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The WELDING Journal

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The Journal of the American Welding Society

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CLARK KICKLESS CABLE showing 720° Torsional Hand Twist in Direction Opposite Helical Winding
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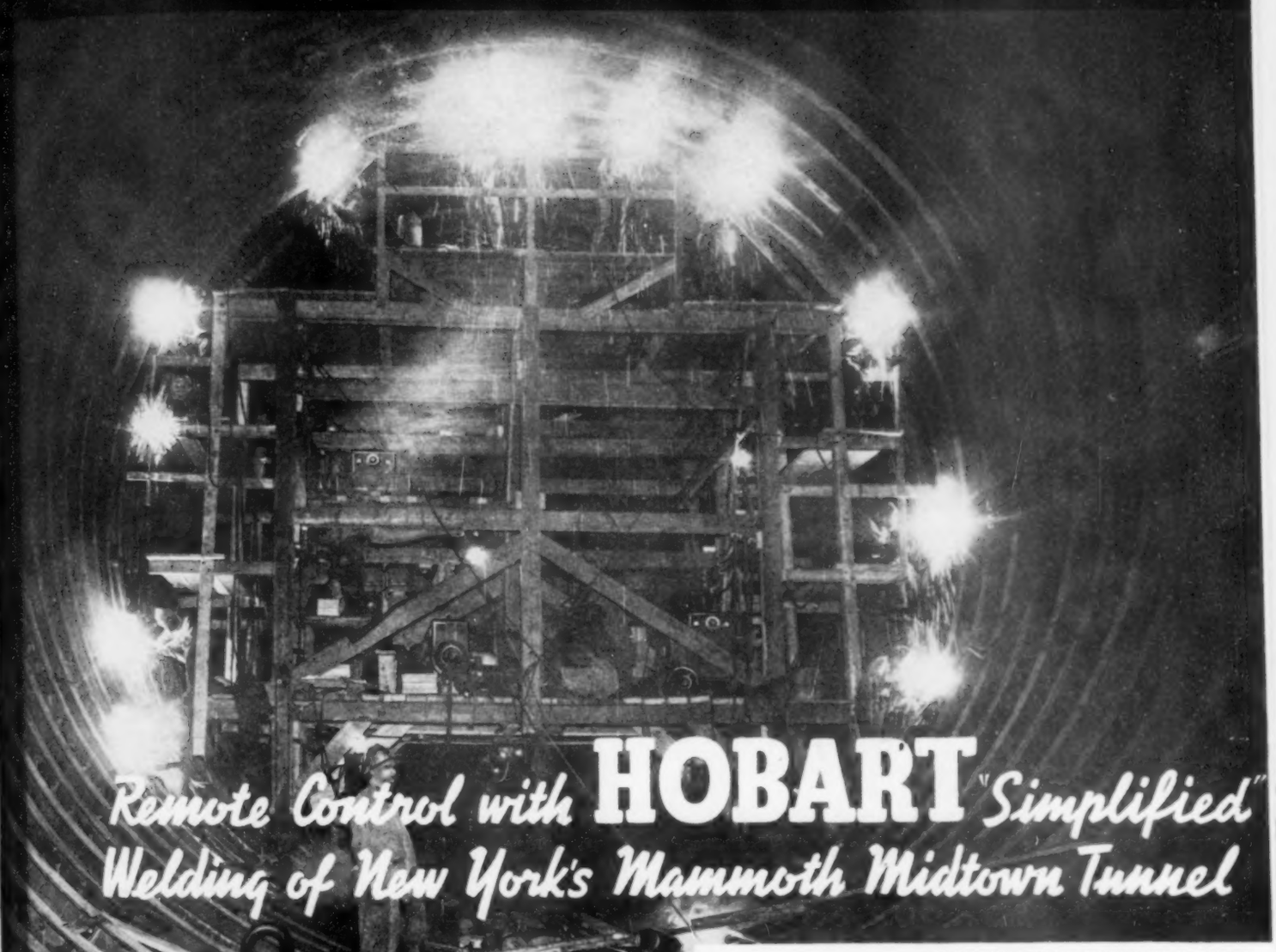

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The American Welding Society Journal

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Welding Rake End of a 195-Foot Oil Barge.

Courtesy Dravo Corporation

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Welding Journal

VOLUME 19, No. 10 OCTOBER 1940

THE PRODUCTION FLAME

Hardening of Machine Parts*

By JOHN ERLER† and P. H. TOMLINSON†

THE art of flame hardening, which basically consists of heating a small area of a ferrous material above its critical temperature with an oxyacetylene flame and immediately quenching in a suitable medium, is not new. The almost universal acceptance of flame hardening as a very effective tool for modern industry is, however, quite recent and dates back only to the development of the Shorter process for selective hardening of gear teeth by the flame method.

In many cases the hardening of machine parts is necessary to produce a structure which either resists extreme wear or produces and holds close tolerance requirements, which are essential for accurate performance during the entire life of the part.

Designers seldom have in mind the higher physical strength properties of the entire mass obtained when specifying full hardness in the upper Brinell ranges.

The meager research data in the field of combined properties of flame-hardened parts may be explained by the fact that the prominence of the process has gained momentum only in the last few years, but the results found by Zimmerman and supplemented by O. J. Horger and T. V. Buckwalter on the improvements of fatigue properties by flame hardening warrant further investigation.

If wear resistance is the reason for hardening, in most cases only certain sections of the machine parts need hardness. The hardening of the parts in their entirety would make machining after hardening costly, if not impossible. Conversely, this represents one of the major economic factors of the process, as a flame-hardened part would present such difficulties only in the relatively small treated areas.

Materials which are suitable for flame hardening, as well as fundamental procedures, have been reported in many articles and papers, a summary of which can be found in the various handbooks and textbooks and papers.

For our needs, steel forgings, rolled stock, steel castings and Meehanite castings are used. The selection is determined by engineering requirements or economic considerations.

Steel forgings and rolled stock are plain carbon steel ranging from 0.35 C to 0.70 C, with the manganese range held within close limits. Any desired hardness can be obtained in this range to fulfil our present requirements. Alloyed steel is selected only for certain core properties. For instance, should a part require hardness as well as be subject to high impact, a steel is selected which can be treated to produce the impact properties which the core will retain after flame hardening. The combined properties obtained by this procedure represent maximum values in their respective areas.

So-called high-alloy, air-hardening steels respond very favorably to flame hardening, but, of course, water must be replaced by air as a quenching medium.

Plain carbon steel castings and those of the so-called pearlitic type, low alloy and medium carbon, are used in our selection. Here, too, carbon steels are satisfactory for most hardness requirements, but the core properties will influence the selection of any alloy steel and its treatment before processing. The factor, limiting the carbon range most, is design. In general, we specify 0.55 C as a maximum with not over 0.80 manganese. This may be varied up or down depending upon the complexity of the design of the casting.

Grey irons of the pearlitic type having more than a 0.60 combined carbon lend themselves admirably to the flame-hardening process. One must realize that the name grey iron represents a large group of various alloys which have their own heat-treating characteristics. We have found that Meehanite metal best fulfils our own requirements. The combination of flame hardening and Meehanite has opened up new fields, because we now have combinations of desired properties, such as damping capacity, retained in the core of the part, and hardened surfaces having small graphite nuclei which form reservoirs for lubricants.

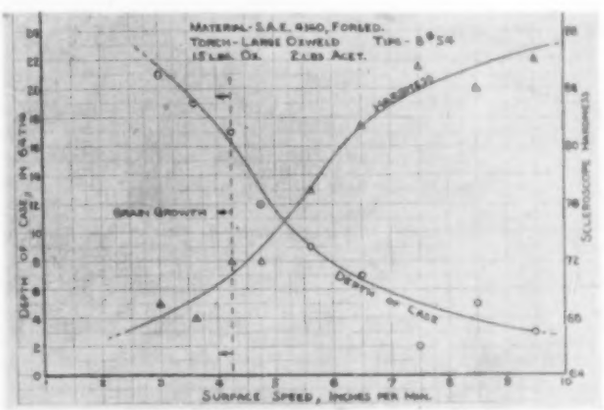
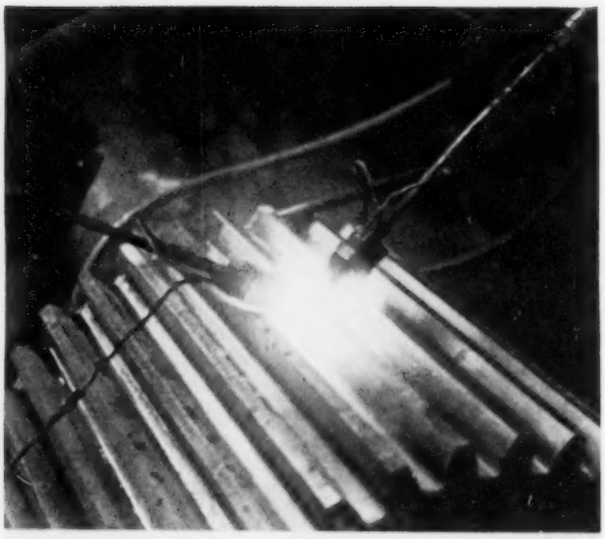
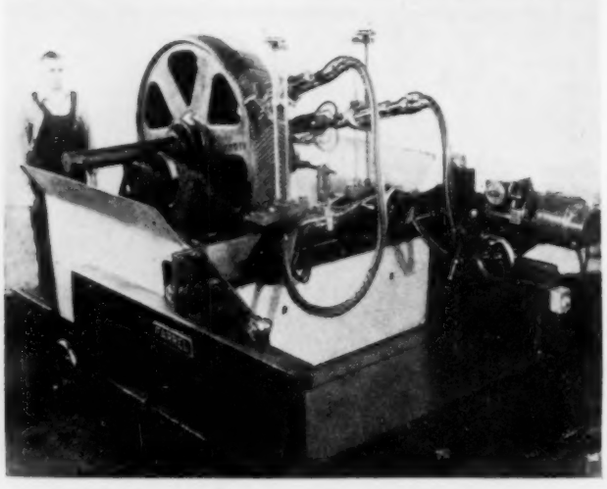

MATERIAL - S.A.E. 4140, FORGED.
TORCH - LARGE OXWELD TIPS - 8 & 54
15 LBS. OX. 2 LBS ACET.
HARDNESS
GRAIN GROWTH
DEPTH OF CASE
DEPTH OF CASE IN 64THS
SCLEROSCOPE HARDNESS
SURFACE SPEED, INCHES PER MIN.

Fig. 1—Depth of Case and Hardness vs. Speed

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Farrel-Birmingham Company, Inc., Ansonia, Conn.





Figs. 2 and 3—Hardening of Gear Teeth and Typical Machines

In order to avoid failure or difficulty in the process of flame hardening, specifications and standards of material are essential before any production methods can be carried out with any reasonable success. Flame hardening is one of the last operations in the manufacturing process of a machine part and failure at this point would be a great loss of both material and time.

The heat analysis of steels should be obtained and checked to assure that the materials are within the range set up by standards. The heat treatment, prior to flame hardening, must be of such a nature as to eliminate or reduce residual stress to a practical minimum. In most cases, an anneal, normalize or liquid quench with a draw of over 1200° F. is necessary. Machine straightening after the primary heat treatment or during the rough machining operation might lead to extensive distortion or cracking during flame hardening. If straightening is necessary, the preliminary treatment should be repeated or at least the part stress relieved at 1250° F. A close inspection for overlaps, cracks, flaws, etc., should be made before the flame treatment starts.

These specifications, as well as the physical inspection, are as important for steel castings as for forgings. Care must be taken in the foundry to keep sand spots, blowholes and shrinks away from the faces to be hardened. The foundry should be carefully instructed as to which surfaces are to be treated so as to protect them from minor as well as major defects. Any welding, which is quite permissible on commercial steel castings, will not only lead to a soft area in a hardened surface, but will cause small checks to occur only too frequently in the zone where the weld joins the parent metal.

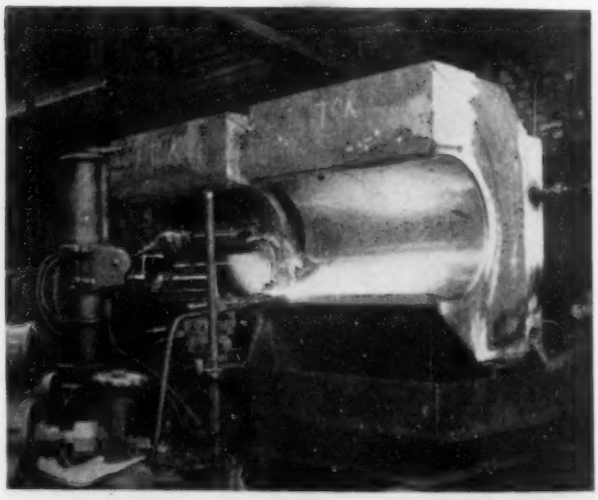
If Meehanite or, for that matter, any iron castings are to be flame hardened, it is advisable to stress relieve them at 1200° F. to eliminate casting stresses. Of course, the inspection as described for steel castings is just as essential for iron.

Machine parts of various metals and alloys will flow through a torch-hardening department, each one having its own hardening characteristics. It is therefore necessary in the selection of materials to keep in mind such factors as hardenability, critical point and heat conductivity, the latter more so than in most other heat-treating processes, due to the speed with which the temperature is raised to the proper quenching point.

After study of design and material requirements, the successful application of flame hardening depends upon exacting procedure and control if any degree of certainty or duplication of results is expected.

In order to investigate these conditions, we developed an inexpensive test from which standards are set up covering a wide range of operating conditions affecting the depth of case as well as the hardness of a given material. Sections of a ring 17 inches outside diameter,

Fig. 4—Flame Hardening Large Cast-Steel Mixing Chambers by the Progressive Method



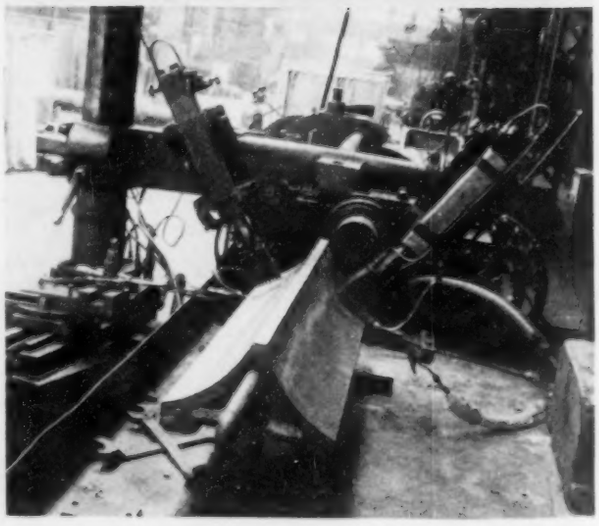


Fig. 5—Set-Up for Progressive Hardening of Discharge Doors

15 inches inside diameter, 1 inch thick are hardened under variable conditions and then broken into pieces and the depth of case, hardness, etc., recorded for each variation. The results are plotted and a curve drawn, as shown in Fig. 1, which is the basis of all future standards for this specific material. We have found that speed is the most convenient variable to control depth of case and hardness.

Flame hardening minimizes distortion as compared to the orthodox way of hardening, but to predict the amount of warpage in both direction and magnitude is often difficult, if not impossible, on new work.

Four basic ways of reducing or eliminating distortion either singly or in conjunction with each other, depending on the design of the part, may be used.

1. Cooling the piece by either submerging the major portion in water or spraying water on certain sections.
2. By machining the piece in such a way that after hardening, the distortion will pull it into the desired shape. This applies particularly to repetitive work where accurate measurements of the distortion can be made and compensated for in later jobs, in the machining before hardening.
3. By physically bending the piece in the opposite direction to the curve of distortion.
4. By increasing the mass in the sections to be flame hardened to give greater stiffness and then removing the extra material from the back or soft side after hardening.

Temperature variation and cooling rate, affected by mass or contour, introduce serious potential difficulties, such as checking or cracking. In order to dissipate the heat uniformly throughout the entire area, and overcome these difficulties which would lead to possible failure of the part, several precautions may be taken. Typical of these are the following:

1. By keeping the flames a reasonable distance from sharp corners or edges so that these areas will not be over heated.
2. Edges of drilled or tapped holes may be protected by filling them with a carbonaceous material, such as so-called electrode paste or with machined graphite inserts. Metal plugs or inserts should be avoided in flame hardening because of stress concentrations set up by their use.

Proper procedure and equipment are important factors in the success or failure of flame hardening, but the deciding element is the ability of the operator, his accuracy and his painstaking thoroughness. We found, in the selection of operators, that the most suitable for this work were young men who had worked in the laboratory doing routine analyses, for a few years. This made them conscious of changes which might occur due to minute variations of operation or procedure. With this background, their training in the handling of the torch equipment can be carried out in a reasonably short time under proper supervision.

This care in selection of operators is particularly neces-

Fig. 6—Flame-Hardened Rings Used in Rubber Mixer

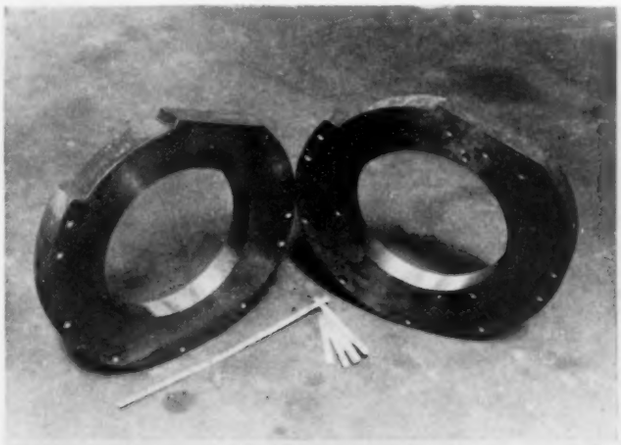
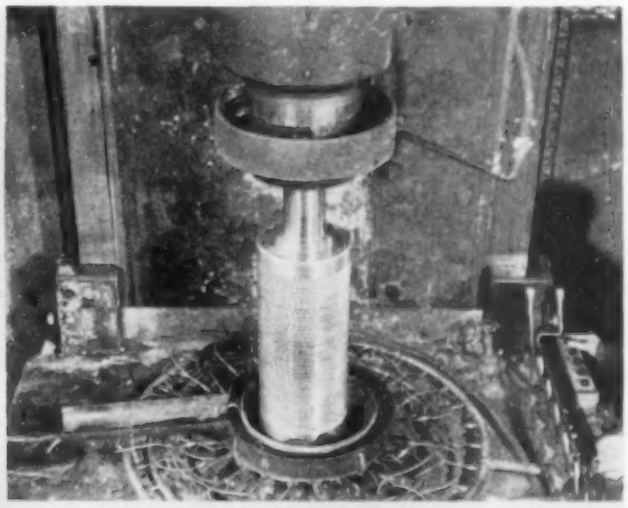


Fig. 7—Set-Up of Flame Hardening Rolls by the Combination Method



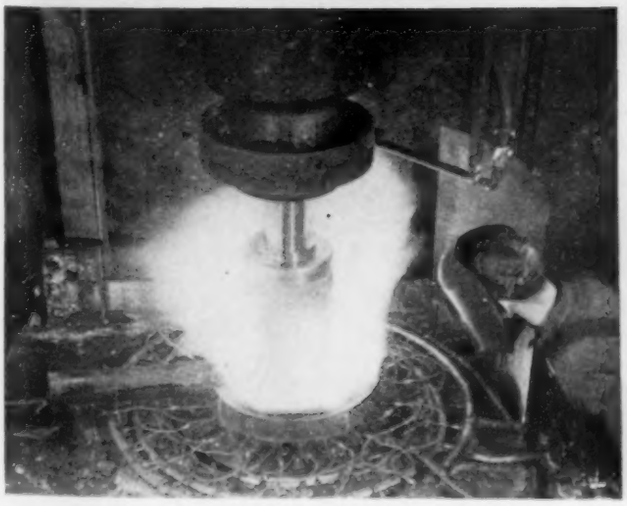


Fig. 8—Operation of Flame Hardening Rolls by the Combination Method

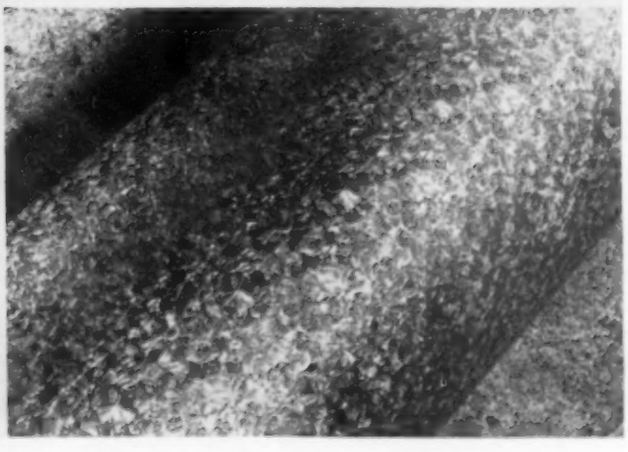


Fig. 9—Close-Up of Flame-Hardened Engraved Roll

Fig. 10—Rings Being Hardened by Progressive Method

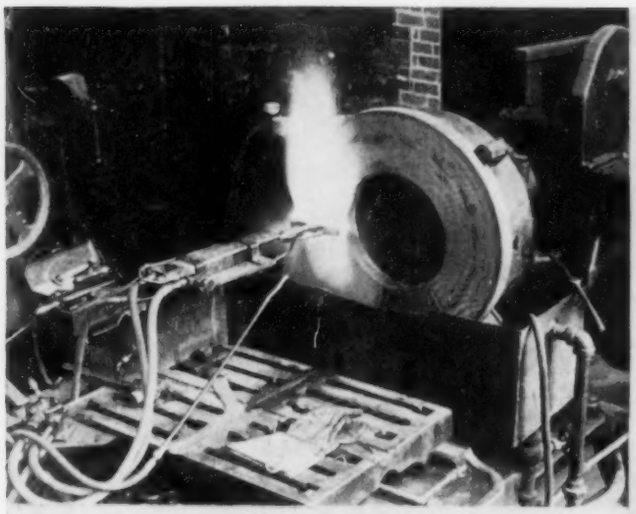


Fig. 11—Adjusting Screws, Shearblocks and Cone Followers. Typical of Types of Smaller Machine Parts Being Regularly Flame Hardened

Fig. 12—Fixtures for Grinding Machines. Typical of Application of Flame Hardening to Machine Tool Parts Cast of Pearlitic Iron

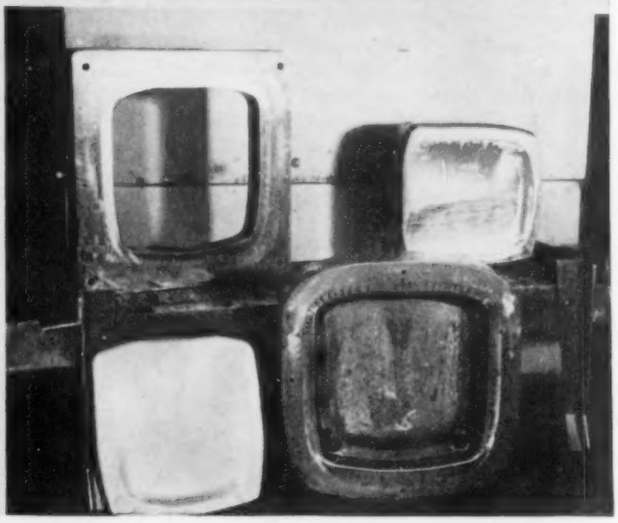


Fig. 13—Chair-Seat Dies Flame Hardened Around Edges to Prevent Scoring. Hardened Area Shows Prominently as a Bright Strip About 1½ Inches Wide

sary, as it is essential to work to standards in flame hardening covering the major variables listed below:

1. Distance of torch tip from piece to be hardened.
2. Distance of quench from piece to be hardened.
3. Distance of quench from the tips.
4. Oxygen pressure.
5. Acetylene pressure.
6. Flame characteristics.
7. Water pressure.
8. Speed of travel.

Some of the dimensional standards must be kept within $^1/_{64}$ inch. This is most important, as in a great many cases it is impossible to make a non-destructive test of the finished piece to determine definitely the depth of case.

Probably the most accurate standard of all is yet to be worked out; namely, the quenching temperature. Methods must be developed to measure the temperature immediately ahead of the quench, a very difficult operation, as the extremely high heat of the flame, as well as its color, is too great an obstacle for present known equipment.

So far, a more or less general procedure has been described, but there are specific problems and limitations which are more outstanding in the application of this process to machine parts than in most other fields of hardening.

Many smaller parts may be completely hardened satisfactorily at a lower cost even though selective hardening would be quite acceptable.

Some long thin section strips distort badly enough to make this heat-treating method undesirable.

Care must be exercised to avoid hardening a very thin section immediately adjacent to a heavy section and around or over cored or drilled holes too close to the edge or surface of the piece being hardened. If these precautions are not followed when designing, cracking is very liable to result.

The sequence hardening of two adjacent surfaces, one at a 90° or less angle to the other, while possible, is not particularly recommended, as a rather unfavorable structure is produced through the root of the angle.

If the above factors can be considered as limitations, a few of the more obvious advantages may be summarized as follows:

1. Ability to harden the wearing surfaces of a piece that is too large to be economically hardened by any other known method.
2. Selective hardening of required working surfaces only, of intricate parts so designed that almost any other method of treating would be a failure due to warpage or cracks.
3. Treatment of limited sections as desired, while still retaining original machinability on the untreated portions.

4. Ability to produce a deep, hard, non-crushing case while still retaining the desirable properties of a soft, ductile core.

5. In many instances, freedom of distortion which makes it possible to flame harden a completely finished object without danger of spoilage.

6. Freedom from heavy objectionable scale. Flame hardening produces an extremely thin, tightly adhering light brown oxide which may be easily removed with one of several inhibited cleaning compounds.

7. The economic advantage of placing hardened metal only where it is required in a particular object is a very strong factor in favor of flame hardening. Many machine parts that could not be economically hardened before the development of this method may now be satisfactorily accomplished, thus improving the product at a minimum cost.

The advantages of flame hardening can best be illustrated by listing a few specific applications of machine parts.

1. Gear Teeth. Reduction of wear and increase of tooth load of a given gear make this application one of the oldest and best known of the flame-hardening possibilities (see Figs. 2 and 3).

2. A machine designed primarily for mixing batch rubber, but now used in scores of industries for as many purposes, is subjected to a great deal of abrasive wear. Flame hardening has played a prominent rôle in increasing the life of numerous parts of this machine.

The cast-steel sides or mixing chambers weighing up to five tons each have the entire bore or working surface hardened. This involves from about 700 sq. in. per side of hardened surface in the smaller sizes to about 4000 sq. in. per side in the larger sizes. Due to the design there is distortion during the hardening operation, but by making proper allowances when machining and by a very carefully controlled procedure, the amount of this distortion is constant within required tolerances and therefore not objectionable (see Fig. 4).

Discharge doors of this mixer are subjected to even more wear than the sides and are therefore also hardened on all exposed surfaces, which number five, two curved and three flat surfaces adjoining each other. Here, again, improved practices have reduced subsequent grinding to about 10% of the original.

A very interesting side light has been brought out in connection with hardening these sides and doors. Progressive hardening has one inherent defect, that of overlaps on wide surfaces or on rings. Due to their size these mixer sides and doors have three or four of these softer zones which it was felt might prove detrimental in service. However, we have discovered that while the overlaps stand out very prominently in a casting that has had considerable service, due to different light refraction or "color," there is no measurable difference in wear in this application between the fully hardened and the softer zones.

Flame hardening of these parts has increased their life from 25 to 50%.

The numerous rings in this machine are also being successfully flame hardened. In some instances very heavily abused sections of some of these rings are hard surfaced by welding and the remainder flame hardened (see Fig. 6).

3. A newer and rapidly increasing use of flame hardening is for rolls and shafts by the combination method. By this method, rolls, solid or cored, cast or forged, smooth, engraved or corrugated, made of steel or Meehanite, are hardened with no measurable distortion, a uniform case and with no soft spots, spirals or overlaps. Hardness readings up to 80 scleroscope have been obtained with Meehanite and 90 or better on some of the steel rolls (see Figs. 7, 8 and 9).

Long, relatively small diameter shafts or rolls are also successfully hardened by the combination method, although there is a little greater danger of distortion being encountered, due principally, we believe, to residual stresses in the shaft being relieved by the heating operation.

4. Adjusting screws from 1-inch diameter to 8 inches and shear blocks are regularly hardened on the ends by the spot or stationary method, to better enable these very necessary mill parts to withstand the occasional heavy wear and almost constant compression load to which they are subjected (see Fig. 11).

5. Heavy centers for grinding wheels and lathes, made both of Meehanite and steel, are similarly hardened.

6. Wobbler sections of spindles and couplings are giving much greater life due to flame hardening.

7. Many Meehanite machine tool parts such as jigs and fixtures are hardened to maintain closer tolerances during subsequent use by reducing the possibility of gouging or scratching (see Fig. 12).

8. Gage plugs for short run or special jobs are much more economically hardened by this method than by the orthodox procedure.

9. External and large barrel-type cams of Meehanite flame hardened, are showing excellent service.

10. Flame hardening has been successfully applied on large Meehanite dies to prevent scoring the face of these castings by the drag of the roughly sheared edges of sheet over it. Only the sections so abused had to be treated and no subsequent grinding or other machine work was required (see Fig. 13).

11. Journal boxes for roller bearings have been hardened with excellent service results. In this application, care must be exercised in design to prevent too abrupt section changes in the hardened areas.

12. Forged-steel bucket pins, used on dredges under very severe working conditions, a combination of sand and salt water, have given remarkable life after flame hardening.

While flame hardening of machine parts is comparatively recent, the process should not be considered merely as replacing any existing methods, but rather as supplementing them. As the possibilities of this art are more thoroughly investigated, its uses will multiply and the life of many machine parts will be materially increased.

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PRESIDENT'S RECEPTION

The President's Reception will be held at the Cleveland Hotel, Cleveland, Ohio, in the Ball Room, Mezzanine, Sunday, October 20th from 5 to 7 P. M. This is an unusual opportunity for getting together and meeting all the officers and prominent members of the American Welding Society before the formal sessions open on Monday. Plan to attend.

DESIGN AND CONSTRUCTION OF Arc-Welded Steel Structures*

By LaMOTTE GROVER†

THE complexity of administration and responsibility for bridge and building construction, and the accompanying inertia toward extensive changes of any kind in construction methods, have been reflected in a high degree of organization and standardization of practices and types of equipment in the structural steel fabrication and erection industries.

Very few structural shops are as yet adequately equipped to execute welded fabrication in such a manner as to realize anything like the full economic advantages that welding presents. The cost of fully equipping a plant for efficient welded fabrication is far below that for a plant of equal capacity for riveted work. It is certain that the cost of welded fabrication is greatly reduced when auxiliary equipment is provided for fitting, aligning, assembling and positioning work that involves a considerable amount of welding, such as girders, trusses, built-up chord members and columns, and other assemblies.

Welding is now competing successfully with other methods in many shops that have no special equipment for the welding, other than welding machines, an inexpensive welding floor and a few small tools and improvised clamping, wedging and holding devices. It is therefore obvious that as structural steel fabricating shops begin to devote as much effort and ingenuity to devising special or universal fixtures, and handling and positioning devices for welding, as other steel fabricating industries have, the savings from the use of welding will increase rapidly.

Naturally, it requires some time for shops to become fully organized for welding, but quite a number of structural fabricators are now making strides in that direction as fast as they can see a volume of business develop that warrants such changes or additions to their plants and equipment. The increasing enthusiasm and interest of structural and bridge engineers in welded construction forecasts a continued rapidly mounting increase in volume of welded construction.

A great increase in volume of industrial building construction is already at hand. Modern practices for such construction demand wide unobstructed floor spaces and well-lighted and ventilated workshop interiors of clean-cut and pleasing appearance. The types of rigid frame, steel arch and long-span light-truss framing that are required to meet these demands offer particular advantages for saving through arc-welded construction.

IMPORTANCE OF CONTROL AND SUPERVISION

With the more fundamental features of welded design, good workmanship and technique of welding having become developed into quite well-established practices, the major attention of welding engineers and technicians is becoming focused upon means of control to effect the best economy of welding and to insure unquestionable reliability of more complex welded assemblies.

Rules of safe practice have been formulated which insure the making of sound and highly efficient welded joints *when conditions attending the assembling and welding operations are properly controlled.*

Many welding firms under competent and experienced supervision have developed a resourcefulness for properly controlling these attending conditions for various kinds of welded assemblies. They have learned how to control shop and field operations in such a way as to insure reliable results and at the same time execute their work in an economical manner, without wasting weld metal and with a minimum of costly straightening operations to correct distortion. A system of rational control in such shops has come to replace to a great extent the costly experimenting by trial and error that was once more common.

The problems encountered are often made much more difficult than necessary by improper design, a thing that is usually beyond the control of the structural fabricating shop, because designing engineers are often reluctant to change features to facilitate welding after a contract has been let. Many times design features that are originally adopted with the thought of being extremely conservative, work out in the long run to defeat that intent because they introduce complications that make it very difficult to control welding operations in a reliable manner.

It has been widely recognized that the administration of welded construction must include qualification of welding operators and of filler metal, and some kind of engineering inspection to see that proper specifications for workmanship and welding technique are followed. The equal, or perhaps even greater importance of assuring intelligent control and supervision on the part of the fabricating shop or contractor, and the part that good

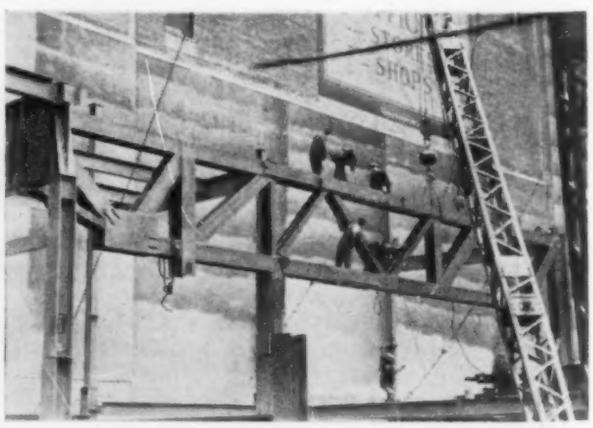


Photo courtesy of Lehigh Structural Steel Co.

Fig. 1—Good Fit-Up in the Erection of 30-Ton Trusses for Air Lines Terminal in New York Reflects Well-Organized Shop Work

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Structural Welding Engineer, Applied Engineering Department, Air Reduction Sales Company, New York.

Photo courtesy of L'Ossature Metallique

Fig. 2—Simple and Inexpensive Provisions for Positioning Are Used When Duplication Is Not Enough to Warrant Elaborate Devices

design plays in facilitating this control, have not received as much recognition as they merit.

In welded construction probably more than in any other kind, economy as well as the success of the final operations in producing sound structures depends upon the kind of work that has been done in the preceding operations of designing, detailing, laying out the work, preparing material, fitting and assembling, and planning the sequence, position and other conditions for welding operations. It is therefore most important for the designer to visualize all these operations in connection with the details that he uses, and for the shop and field work then to be carefully organized throughout all operations.

One of the purposes of this paper is to correlate design and shop-practice requirements in such way that the designer and the shop man, each one, may better understand the other's problems.

PROPERTIES OF MATERIALS AND THEIR RELATION TO DESIGN

Fully competent design must be predicated upon a knowledge of the behavior of engineering materials under the conditions that attend construction operations as well as conditions of service. Too many engineers, however, have been content to use more or less standardized details under all conditions that arise, and to assume blandly and confidently that their design assumptions will be fulfilled perfectly.

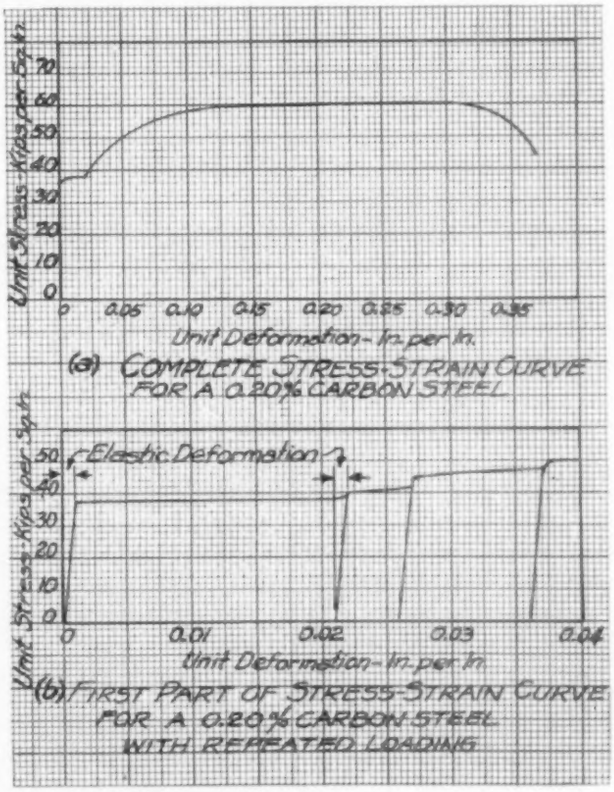
Designers have a habit of assuming that the material in their structures comes miraculously through mill, shop and erection operations without any of it having been stressed or deformed beyond the elastic limit, and that it arrives in final position, practically free from stress until it assumes the loading for which it was computed.

Nothing is further from the truth, regardless of whether the material be steel, concrete, wood or some other material. In any kind of steel construction, the material, in passing through various stages of mill and shop operations, is hot worked, cold worked, bent and formed. It is at all times in a condition of balanced localized internal stresses with peaks that often reach yield-point magnitude. Differential rates of shrinkage during cooling after rolling set up such stresses. Then during and after erection the steel is unavoidably subjected to incalculable secondary and concentrated stresses until it yields and becomes adjusted to service conditions, still in a condition of internal stress of yield-point value at some points. That is why specifications for structural steel have requirements for ductility and other properties that permit the material to yield locally and relieve these local balanced, secondary stresses as load stresses are induced, so that the two will not combine to cause structural damage.

The facts mentioned above might be thought of as cause for great apprehension, if viewed with no knowledge of the behavior of structural steel, and if it were not for the excellent experience record of the reliability of steel construction.

Several facts about the stress-strain curve for a ductile carbon steel are often forgotten by structural engineers. The deformation up to the yield point is very small, something like 0.10%, too small to be represented in Fig. 3 (*a*), which is the complete stress-strain curve for a 0.20 carbon steel. Fig. 3 (*b*) is approximately the first one-ninth part of a curve like Fig. 3 (*a*), drawn to a much larger deformation scale. From these figures it is seen that the deformation up to the yield point (mostly elastic) is only about $^1/_{22}$ of the total deformation to the end of the "plastic" stage in which deformation takes place without increase in stress. This means that when a *self-limiting* condition causes a stress of yield-point value and an accompanying deformation that is perhaps somewhat more than yield-point deformation, and this condition is followed by a loading of the member, then only a very small amount of the available stretch in the plastic stage is sufficient to relieve the initial stress.

By releasing the load and then applying it again at several points, as illustrated in Fig. 3 (*b*), it is demonstrated for any of these points that part of the total deformation (which is mostly permanent set) is an elastic portion approximately equal to that which occurred before the yield point. The assumed initial stress corresponding to this elastic deformation is relieved as loads come onto the structure. Of course, this is true



Experimental Data courtesy of Professor James E. Boyd, Ohio State University

Fig. 3—Stress-Strain Curves for 0.20 Carbon Steel

only when the initial stress results from a self-limiting condition such as shrinkage or self-limiting rotations of the ends of members.

The properties of ductility and toughness in steel are largely responsibility for its versatility and superiority in being able to adjust itself without structural damage to the requirements of practicable construction operations.

Harassing as it may seem to some engineers to think of the materials in their structures being subjected to strains that do not appear in their stress computations, they must become reconciled to actual facts for an intelligent use of these materials. Whether they be steel, wood, concrete or other materials assumed to behave elastically, there actually exist very high secondary stresses due to differential shrinkage in cooling, drying or setting up, and due to plastic flow or permanent yield, etc., that could be viewed with equal disquietude, if not well understood.

Fortunately, in most cases no serious difficulties are encountered despite neglect by the designer to recognize fully the behavior of his materials of construction, because he uses for the most part details that have been found to stand up in practice, even though they may, on the one hand, be grossly wasteful of material, or, on the other hand, be encroaching seriously upon the factor of safety. If a special detail gives trouble, the conclusion usually is merely that it is a bad detail and should be avoided in the future, whereas there is really a fundamental reason for the misbehavior, that is directly related to the natural behavior of the material.

From the stress-strain curve, Fig. 3 (*a*), it is seen that steel will stretch or deform a considerable amount after passing the yield point; but if it is called upon to deform too much, then real structural damage becomes imminent (Fig. 4). If the form of a detail or the presence of

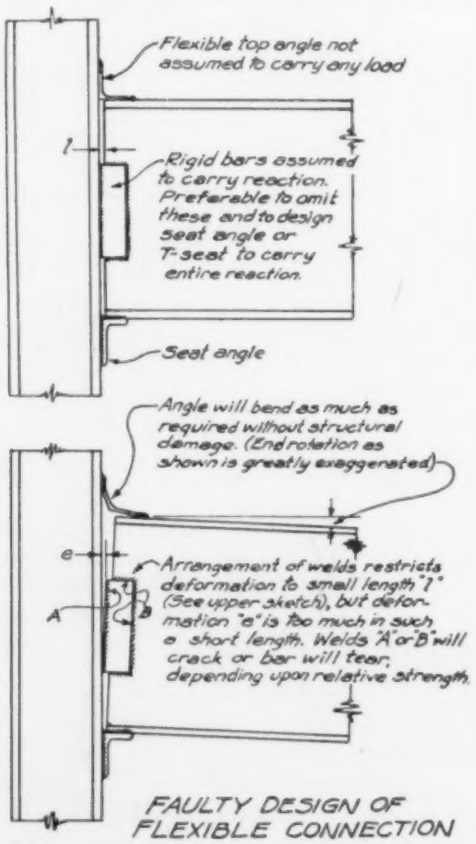

Flexible top angle not assumed to carry any load
l
Rigid bars assumed to carry reaction. Preferable to omit these and to design seat angle or T-seat to carry entire reaction.
Seat angle
Angle will bend as much as required without structural damage. (End rotation as shown is greatly exaggerated)
e
A
B
Arrangement of welds restricts deformation to small length "l" (See upper sketch), but deformation "e" is too much in such a short length. Welds "A" or "B" will crack or bar will tear, depending upon relative strength.
FAULTY DESIGN OF FLEXIBLE CONNECTION

Fig. 4—Faulty Design of Flexible Beam-to-Column Connection

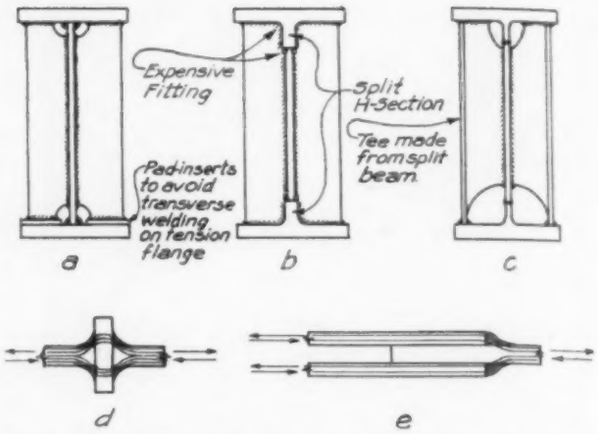


Fig. 5—Relation of Nature and Direction of Stress to Forms of Welds and Types of Joints

small cracks or other serious defects causes deformations to be restricted to comparatively small areas or volumes of metal, there is no opportunity for the ordinary mechanisms of behavior to occur, and a ductile material may behave in a brittle manner before relief can be furnished through plastic flow or stretch.

Secondary stresses may be caused by differential shrinkage in mill or shop operations, by cold working, by such partial restraint against end rotation of beams as occurs with standard "flexible" end connections, by sharp corners or by other conditions not recognized in design computations. Differential shrinkage stresses are nearly always quite highly localized and balanced, because areas subjected to tension are adjacent to areas under compression, and the total internal stress across a section is zero if there are no external forces acting at the ends of the member.

These secondary stresses are usually self-limiting and are relieved (because they are not caused by external forces which could follow up and continue the stress after yield has taken place), provided the metal is not prevented from behaving in a normal manner (by circumstances such as have been pointed out) and providing it is not called upon to deform an excessive amount.

Designers and shop men, alike, should be familiar with these properties of steel, both within the elastic range and beyond it, so they will understand the limitations of what may be expected of the behavior of steel and thereby avoid difficulties that might otherwise be experienced from time to time.

Many of the fundamentals of good design practice for welded construction have been stated, a number of them at a time, in various articles that have been published in the JOURNAL. A summary of the most essential requirements for good technical design and good economy is appended to this article.

MAGNITUDE OF SHRINKAGE STRESSES

From a lack of understanding the behavior of steel at higher temperatures, some engineers have been led to an erroneous conclusion regarding the magnitude of shrinkage stresses. They assume that if a welded joint and the adjacent base metal would shrink, say one-eighth inch, if not restrained in any way, but that this shrinkage is prevented by restraint, then the shrinkage stress in the member will correspond to such a stress as would be caused by a one-eighth-inch deformation effected in the member by an external force while the steel is at normal

service temperature. They fail to recognize that while a major portion of the cooling is taking place, the metal is in a hot plastic stage in which a very small restraining force will prevent shrinkage without setting up appreciable stress.

Also, it is sometimes erroneously assumed that under conditions of restraint, the amount of shrinkage stress will be that computed for a deformation equal to the product of the average drop in temperature of the piece, its length and the average coefficient of thermal expansion. Again, no consideration has been given to what happens in the hot plastic stage where the yield-point stress is so low that no appreciable shrinkage stress begins to build up until the weld metal cools to 500–600° C. Up to that time the shrinkage is relieved through plastic deformation.

What must be guarded against most carefully is a condition during heating and cooling that may subject a comparatively *small area of metal* to highly concentrated stress that it cannot withstand, either because of the intensity and multiaxial direction of the stresses or because of the form of profile or section and the physical properties of the metal that exist temporarily. The depositing of too small a root pass for a weld in heavy material is an example of this condition, which may result in weld cracks or defects that may spread and open up. Such defects prevent ductility from being manifested in a normal manner while the steel is adjusting itself to conditions of service and temperature. It is particularly necessary to guard against such conditions when certain high-strength alloy steels of difficult weldability are used, and when thick material or rigid assemblies are being welded.

NATURE OF STRESS AND WELD FORMS

There is one point which it is particularly timely to stress at the present stage of development in design for welding. Research has demonstrated the virtue of certain forms of welded joints under particular conditions regarding kind and direction of stress and the nature of its applications. Sometimes these forms involve a considerable amount of extra cost in the way of accurate cutting to length and preparing of material, as well as in the welding itself, which may require more deposited metal, or a more costly procedure and sequence of welding to obtain the form in question or to control distortion. When the stress conditions warrant the extra expense, it is more than offset by the saving in main material, provided that the schedule of working stresses provides for suitable variations in recognition of different stress conditions. When the stress conditions are not such as to require more expensive forms of welds, their use is grossly wasteful, in the same way as the specifying of sizes of welds larger than required by stress analysis, or larger than the minimum sizes specified from consideration for proper welding conditions.

In either case, a desire to be conservative will often work out in just the opposite manner, by making the welding more difficult or introducing difficulties into the control of shrinkage stresses.

A good example of this is the comparison of two built-up girder forms (Fig. 5 (*a*) and (*b*)). One of these (Fig. 5 (*a*)) is constructed by joining two plain flange plates to a square-edge web plate by means of the kind of fillet welds that are produced by a normal welding procedure, miter shaped, with perhaps a limited amount of convexity. This type of section is still used commonly in this country, and in England for railway bridges as well as highway bridges and building girders. The fillets are subjected to longitudinal shearing stress parallel to their length, as compared with the combined shear and tension in the concave and ogee-shaped transverse fillets, pictured in Fig. 5 (*d*) and (*e*) as being subjected to reversed fatigue stresses. The advantage of providing these special forms of welds for the cases illustrated in Fig. 5 (*d*) and (*e*), to provide lines of smooth stress flow, has been demonstrated conclusively.

In Fig. 5 (*b*) and (*c*) are diagrammed two types of welded girders that have been used in this country recently on a few occasions, simulating practices in Continental Europe where special flange sections are rolled for such use instead of using split-*H* or split-beam sections.

The comparison of costs for preparation of material fit up, assembly and welding are overwhelmingly in favor of type (*a*). There can be little doubt that this type is entirely suitable for building girders and highway bridges. Even for railway bridges in which fatigue and impact conditions are more severe, the records of experience indicate that the butt welds of Fig. 5 (*c*), as used in Continental Europe, may have needlessly complicated welding conditions. Not that this type cannot be constructed under proper conditions with full assurance of reliability; but in Germany difficulties have been encountered in girders of this design, due to the use of a special high-strength alloy steel that was at the best difficult to weld and to an improper sequence of assembling and welding. The web stiffeners were put in place and fit so tightly between the flanges prior to making the web-to-flange welds, that shrinkage of these welds was prevented, with the result that cracks and defects resulted.

An example of a very desirable use of butt welds is that of a splice in a tension element, such as the tension flange of a bridge girder. Under repeated stresses such a joint, without excess "reinforcement" or convexity (which actually weakens a butt weld), has been proved to be much more efficient than either welded or riveted strap splices, which cause deviations in the lines of stress flow across the joints. Entirely butt-welded splices have come into quite common use for beams and girders.

SHOP FABRICATION AND WELDING

There are a number of axiomatic principles governing the organization of welded fabrication work that should be stressed particularly for structural plants where both welded and riveted work are usually carried out. Most of the principles for good economy as well as reliable control, being the same as have been developed in other classes of welded steel fabrication, will be sketched rather briefly.

Adequate shop space should be provided, *exclusively devoted to welding* and equipped with a rigid, accurately leveled welding floor or grid, buggies, cranes and hoists, of suitable types and capacities for the class of work to be undertaken. For best efficiency and control, the special equipment for welding should include fixtures and positioning devices for parts or members that involve extensive welding.

There is much less heavy handling or moving of parts to be done in welded fabrication than in riveted work, so less extensive handling equipment is required. Most of the work on a welded member or assembly is done at one point, whereas riveted work keeps moving along as various operations are performed. It is obvious that no extensive amount of welding can be done in areas where riveted work is being carried out, without serious loss of efficiency. Preliminary operations such as shearing,

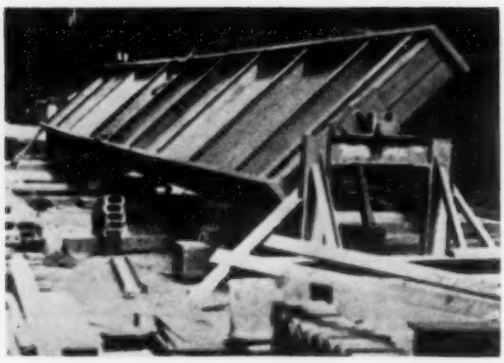


Fig. 6—This Trunnion-Positioning Device Used for Welding a Railway Bridge Girder Can Be Made Largely from Scrap Material

straightening and cutting to length, as well as finishing, cleaning and painting, can be done in the same areas for both classes of work.

More extensive gas cutting and gouging, and less coping, blocking, beveling and trimming with shears are involved in welded fabrication. This is in part because the edges of thicker material may be physically injured by either shearing or rough planing (as in the ordinary edge planer), to a greater depth than that reached by the fusion of welding; and even severe work hardening, followed by the heat of welding, if not controlled carefully, may result in adverse metallurgical effects. Also, accurate fit-up, which is very important for economy as well as reliability, can hardly be assured for sheared edges. Any extra cost of gas cutting or flame machining over that of shearing will be largely offset by the elimination of some handling of material.

Auxiliary devices and equipment include small temporary clamps, cleats, stops, lug angles, blocks, yokes, etc.; holding down devices such as cams, eccentrics and wedges; jigs, fixtures and rotating, tilting or rolling devices for positioning the work.

Jigs, fixtures, assembling and positioning devices can often be made largely from scrap material (Fig. 6), but an amount of careful study, design and expense should be devoted to them, commensurate with the form and number of duplicate pieces to be fabricated. Many of these devices can be made of a somewhat universal design that can be accommodated easily to different sizes and lengths of members or assemblies (see Figs. 2 and 7).

The essentials of good fixture design are in general the same as have been recognized in carrying out other classes of steel fabrication by welding. Fixtures should be strong and rigid enough to retain their shape, and especially so when preliminary deforming of material is necessary to compensate for tendency to distort under unbalanced applications of welding. If of the tilting type, they should be capable of being oriented into the most convenient and economical positions for the welding.

They should permit rapid, easy and sufficiently accurate assembly of parts, and quick removal, without necessity for hard driving of parts to get them in and out. The devices for holding parts in place while an assembly is being rotated or revolved into different positions for welding, should be easily operated and located so as not to foul welding operations or get heated up by the welding so as to impair their manipulation or throw parts out of line. Usually the most simple and most easily made devices are the most convenient and effective.

The more duplication of pieces, the more the organization of the work will be similar to that used for mass production, with a great deal of study devoted to the first piece and the facilities, procedure and sequence for fabrication and welding, so that all difficulties can be ironed out and corrected before production starts.

When only a single piece or very few of a kind are involved, a comparatively simple device for rotating the work into the best positions for welding may be the most economical, supplemented by improvised props to help support and steady the assembly (Fig. 2).

IMPORTANCE OF CAREFUL PREPARATION OF MATERIAL AND GOOD FIT-UP AT WELDED JOINTS

When poor fit-up occurs at a fillet-welded joint, specifications require the size of weld to be increased by the amount of the gap between the parts, so that the full calculated strength of the weld will be provided. The volume of weld metal in a fillet increases as the square of the size. It is a simple matter of geometry to show that when, for example, a $^1/_4$-inch fillet must be increased to allow for a gap as small as $^3/_{32}$ inch, the volume and cost of the weld metal are almost doubled, to say nothing of the increased difficulty of welding under conditions of poor and irregular fit-up. When decreased efficiency of the operator, greater waste of electrodes, etc., are taken into consideration, the cost per foot of weld may almost triple, as a result of poor fit-up. The increased cost of careful preparation of material to avoid such conditions is very small by comparison.

Poor fit-up at the root of a butt weld results in greatly increased cost in the same manner. If a root opening is required, as for V-welds, but there is no gap, there will be poor root penetration, and heavier gouging or chipping out and back welding will be required. If the opening is too great, an extra amount of weld metal will be required, equal to the product of the excess clearance multiplied by the plate thickness and by the length of joint. Greatly increased difficulty of welding is involved in this case also.

In the case of either the fillet weld or the butt weld, the excess weld metal over that needed will often be enough to complicate control of distortion. Also, where the effect of inaccuracies is cumulative it may even result in such misfits as to make the part a total loss. An irregular gap or fit makes welding especially difficult to the point where it is sometimes almost impossible to avoid defects.

In field welding the difficulties caused by poor fit may be much more serious, under some conditions resulting in distortions, high shrinkage stresses or misalign-

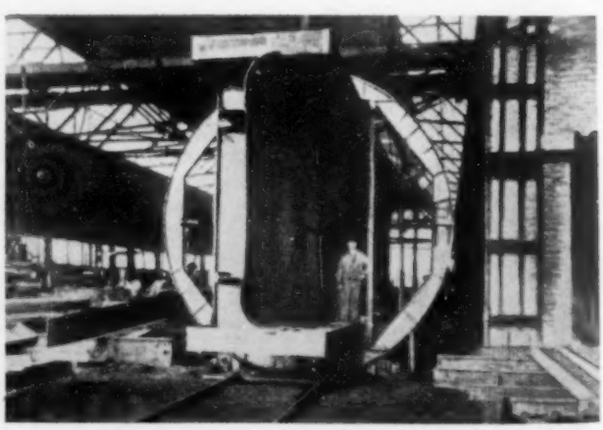


Photo courtesy L'Ossature Metallique

Fig. 7—Entire Superstructures of Railway Girder Bridges Have Been Positioned at Small Expense with Rotating Frames and Dollies

ment, that are very expensive to correct. Also the cost of depositing extra weld metal is much greater in the field. The practicability of providing close fit-up for erection was well illustrated in the erection of two 30-ton trusses, each 70 feet long, in the new Air Lines Terminal in New York City (Fig. 1). To one end of each truss a short section of *H*-column was welded in the shop. This had to fit perfectly into the alignment of the supporting building column in the field. The other end of each truss was welded directly to the web of a short transverse plate girder, which frames into a line of columns at each end. The trusses were shipped in two sections with a milled compression chord joint occurring in each field splice between the sections. Despite these complications, the field joints were all made without difficulty.

ERECTION AND FIELD-WELDING ORGANIZATION

It might be expected that field erection of welded structures would be organized in a special manner. However, with the work of erection crews as highly organized as it necessarily has become in many cities, because of union labor regulations and relatively high labor costs, any influence upon general procedures that might result from the use of welding instead of riveting, could not be expected to manifest itself in erection as soon as in shop fabrication.

In the erection of bridges and industrial mill type buildings, it can often be arranged to avoid all punching and drilling of main members by using erection cleats, clamps and wedges, or welded clip angles with holes for erection bolts. Such erection-bolt clip angles are commonly used for tier buildings also, but the elimination of erection bolts altogether has not yet met with widespread adoption, especially in the case of tall buildings, although the use of patented devices such as all-welded erection seats have been used quite extensively in some localities. It is interesting to observe that in welded tank erection an evolution in this regard has reached the point where all holes in tank plates are usually eliminated. The welding-groove roots are spaced properly and the plates held in position by means of clamping devices.

It should be stressed with regard to field work that a few dollars spent to provide adequate, light-weight and easily transportable scaffolds or platforms for the welding operators to work from with ease and convenience, will not only insure reliable work by permitting the operator to devote full attention to his work, but also such investment will be more than regained through increased efficiency of the operators. In particularly dangerous locations, the provision of safety belts does much to take worry off the operator's mind.

PROCEDURES AND SEQUENCE OF WELDING

Contract specifications usually prescribe limitations on features of welding procedure, sufficient to assure good workmanship. Further complete standardization of all details of procedure should be adopted by each shop for best efficiency, rather than leaving such details up to each operator. If carefully administered, such a system will not curb any worth-while ideas or ingenuity on the part of the individual operators.

Some shops use a general-purpose, all-position electrode, for all work, even though most of it is done in the down-hand position and could be carried out more economically and sometimes in a more reliable manner if the most suitable and most efficient class of electrode were used for each application. This choice of electrode should be a part of the established procedure and not left to each operator.

For members such as rolled beams and columns for tier buildings, which require welding for only the connections, and in the fabrication of light and comparatively flexible material, as for roof trusses, there is little chance for encountering difficulties.

In the welding of heavy material and rigid assemblies, and in making butt welds between parts of unequal thickness, and in splicing *H*, *I* or more complex sections by butt welding, very careful attention must be given to planning in advance all special details of the procedure and sequence of welding.

Local preheating may be required (usually little more than to 100 to 130° F.) to prevent too rapid chilling of the weld metal by thick material. Preheating, or heating some local regions while welding is being performed on others, may be advisable at times to prevent differential shrinkages that would result in distortion or objectionable shrinkage stresses.

Extensive preheating for this last-mentioned purpose may be the only solution in automatic welding, in which step-back, skip or wandering sequences are impracticable and would defeat all the economic advantage of the automatic set-up.

In manual welding, distortion and shrinkage stresses have been controlled in an entirely satisfactory manner for many years now, by using a properly planned sequence of welding, and at much less expense than that of extensive preheating operations. The efficiency of manual welding is not seriously reduced by employing such special sequences.

As a matter of economics for any application, a cost comparison should be made between automatic welding with any preheating that must accompany it and manual welding with distortion and shrinkage stresses controlled largely through a planned sequence of welding and perhaps some local auxiliary heating in special cases.

The control of distortion and shrinkage stress by sequence of welding is a subject in itself. A number of special applications have been discussed by the writer in an article that was presented in the September 1940 issue of the AMERICAN WELDING SOCIETY JOURNAL, to outline practices in making butt-welded splices in beams and girders.

SUPERVISION AND CONTROL OF OPERATIONS

An engineer or superintendent who thoroughly understands the importance of correlating all operations for the best over-all economy and reliability should be in charge of all work. A continual over-all check-up should be provided to see that there is no negligence along the line at any place, and that mistakes are corrected, or pieces discarded if necessary, before further work has been wasted on them.

Difficulty is often experienced in finding competent and experienced personnel for such supervision. This condition has led many shops wisely to pick men from their own organizations to train for these positions, in the same way that they have come to the system of providing classes for the training of good workmen in their organizations to become welding operators.

There is a legitimate place in our economic industrial organization for competent consultant welding engineers whose services can be employed by a plant, to come in and develop an organization for fabrication by welding and to train employees to carry on such work.

APPENDIX

FUNDAMENTALS OF DESIGN FOR WELDED STRUCTURES

Design fabricated members as well as connections specially for welding, dismissing riveted prototypes from mind. Overlapped material, necessary in riveted work, is often unnecessary and undesirable in welded details. (E.g., plain bar web stiffeners for beams and girders are more efficient than angles.)

Visualize all construction operations while designing a structure, and detail fabricated parts and connections with a planned sequence of welding in mind which will permit a control of distortion and shrinkage stresses.

Do not specify steels of unknown weldability characteristics, and if special steels are used, specify electrodes or welding rods and welding procedures that are known to be suitable for such steels.

Provide full and definite information about all welding by means of adequate symbols such as the Standard A. W. S. Symbols (and notes where necessary), referring to standards or special types of welds and to workmanship specifications for making them.

Take advantage wherever possible of the natural adaptability of welding to continuous and rigid frame types of construction in which rigid joints are required. Remarkable savings in cost can often be realized with this type of welded construction.

Let simplicity of detail be the keynote of design. The most simple welded detail is usually the best technically and the most economical. (Note that welded girders are usually composed simply of two flange plates and a web plate, with bar stiffeners where required.)

Whenever simply supported beams or girders are involved (as in tier buildings without windbracing), make definite provisions for sufficient flexibility of connections, such as is afforded by standard riveted connections, to permit end rotation of beams that must accompany simple beam deflection. In such cases the welds must be proportioned strong enough to insure deformation in the base metal.

In welded splices and connections, investigate stresses in both the welds and the base metal to determine the critical section, as in riveted work.

Do not use larger welds than required from stress considerations or from stipulations as to minimum size. This is not only wasteful but in many cases it may introduce undesirable shrinkage with consequent distortion or residual stresses. Also avoid large unnecessary concentrations of welding at one point. (E.g., clip the inner corners of bar stiffeners for girder webs so that the welds joining the stiffeners to the girder will not extend to and intersect the web-to-flange welds.)

Remember that small-size fillet welds provide more effective cross-sectional area per unit volume and cost of weld metal than larger sizes. Smaller size continuous welds are better and more efficient than larger size intermittent welds were a choice may be made. The $^{5}/_{16}$-inch fillet is most common because it is the largest permitted by most structural specifications to be deposited in a single pass.

Avoid eccentricities in connections as much as possible and take into consideration any appreciable ones that exist even though they may be customarily neglected in standard riveted connections. (E.g., eccentricities are not neglected in welded beam connection-angles or tees, in computing the welds joining the connecting material to the web of the beam.)

Avoid so-called "notch effects" that induce concentrations of stress. Arrange details so as to avoid abrupt changes in contour or section that would interfere with smooth paths of stress flow. (E.g., in a welded girder with no rivet holes in the flanges that would constitute "stress-raisers" and interruptions of lines of stress, it is best practice, especially for bridges, crane girders, runways and other dynamically loaded girders or beams, to avoid transverse fillet welds across tension flanges at points of high stress, and to weld ends of bar stiffeners to small fills or pads inserted with a tight fit between the flanges and the ends of the stiffeners after the girder has been otherwise completely welded. Also avoid so-called "reinforcement" of butt welds. Make their surfaces only sufficiently convex to insure full cross section equal to that of base metal.)

Use butt-welded splices in preference to fillet-welded strap splices for dynamically loaded members. Butt welds offer better resistance to repeated stress and shock because they transfer stresses more smoothly. But be sure that a sequence of welding is adopted that will provide for contraction during welding without creating distortion or excessive shrinkage stresses. This is particularly important for members welded into rigid assemblies and for splicing wide plates or sections other than rectangular in shape.

Where the type of joint has no influence upon the size of main material, fillet-welded lap joints are likely to be more economical because they permit making allowance for mill tolerances more easily and the expense of cutting to exact length and of accurate preparation of edges for butt welds is avoided.

For fillet-welded connections used a combination of transverse welds with longitudinal welds to obtain the smoothest flow of stress lines and the best stress distribution. "Box" or return fillet welds by extending them full size around adjacent corners, especially where a longitudinal fillet theoretically ends at a corner where it is not adjacent to a transverse weld and there would be nothing to relieve the stress concentration that occurs at the end of a longitudinal fillet weld.

Avoid details that would cause *progressive* bending or rotation (that is, not inherently self-limiting) about the longitudinal axis of a fillet weld in the direction that would cause tension in the root. Also avoid details that might cause progressive tearing of fillet welds from one end toward the other, similar to the "unbuttoning" of a line of rivets in tension due to bending.

Arrange details so that the heat applied in welding will be balanced on either side of a member as much as practicable, thus relieving tendency toward distortion.

Arrange details so that they will provide easy access for performing the welding with the electrode in the correct position.

Exercise care in using welds along with rivets and bolts (computed to carry stress) in the same structure. If grouped together in a new connection the rivets cannot slip to develop bearing and assure the taking of their full share of the load.

Bolted field connections for light-weight secondary beams, when permitted by the code, work out in a satisfactory manner in conjunction with welding for other field connections and for shop work. Often some cost may be saved by shop welding even though field connections are riveted. But when field welding is adopted to eliminate noise, and welding is not adopted for the shop work also, a very unfavorable combination for economy is invariably developed.

Detail connections and joints to provide as much welding in the shop and as little in the field as possible; also so that as much of the welding as possible can be done in the down-hand position.

Do not reduce weight of material at the expense of such an increase in cost of fabrication and welding as to more than offset the saving in material.

Provide duplication in parts or sufficient similarity for the use of jigs or fixtures wherever practicable.

Where holes must be provided to facilitate rapid erection, as for tier buildings, and some connections in industrial buildings, under conditions that prevail as to organization of erection work, detail the shop and field connections so as to necessitate punching and drilling for as few parts as possible and in as few heavy members as possible. For best economy, avoid arrangements that require both punching and welding on the same member, wherever possible. Some temporary connections, especially for bridges and industrial buildings, can be made economically with clips, cleats, lugs, etc., and held until welded, but some positive means must be provided to hold members together and align them prior to welding.

WELDED RIGID FRAME STRUCTURES*

By A. AMIRIKIAN†

DURING the past two years the Bureau of Yards and Docks of the Navy Department has undertaken a rather ambitious program of construction involving a great number of welded-steel rigid-frame structures. Some of these buildings have already been completed, others are under construction, while still others are at various stages of design and planning. This program can in no way be considered as a radical departure from the Bureau policy of former years; on the contrary, it may well be called the natural sequence of two decades of engineering progress. During that period efforts have not been confined solely to following the general trend of newer technique, but an enviable record of pioneering has also been created both in the fields of design and construction. As the first decade is marked with the concept of "continuity," resulting in the use of simple continuous beams, the second decade is equally noteworthy for the development and application of a supplementary principle—that of "rigidity," well recognized today in the familiar term of rigid framing.

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940. This paper represents only the personal opinions of the author and in no way reflects the official attitude of the Navy Department.

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IMPORTANCE OF RIGID FRAMING

The principle of rigid framing is not new. For certain loading conditions the resistance of a building bent is entirely dependent upon the rigidity of its connections. In the era of riveting, the designer assigned a dual rôle to the same joint, assuming it to be free or restrained—in accordance with the exigency of design and the convenience of computations. Fortunately, welding has completely eliminated this ambiguity; for a welded connection is essentially a rigid connection and, except in some limited cases where flexibility is provided through the connecting medium, it will behave only as a rigid joint.

The importance of rigidity, as a primary factor for the stability of a bent, may be illustrated by a simple example. Figure 1 shows three conditions of framing in a simple bent; in (*a*) all four joints are hinged; in (*b*) the columns have rigid connections at the tops and hinged at the bases: and in (*c*) the top connections are rigid and the bases fixed. Under a lateral force, applied at the top, the bent in (*a*) will obviously lack stability; that in (*b*), while possessing stability, will bend like a cantilever; and in (*c*) all the members of the bent will bend as in a rigid frame—with the least deflection. We may, there-

Fig. 1. - Types of Joints in a Simple Bent.

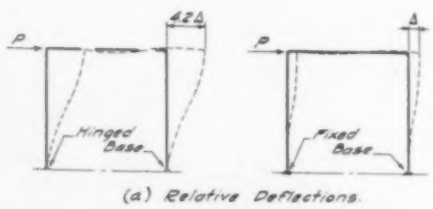


Fig. 2. - Comparative Deflections and Moments in a Two-Legged Bent with Hinged and Fixed Bases, Subjected to a Lateral Force All Members of Equal Stiffness ($\frac{I}{L}$).

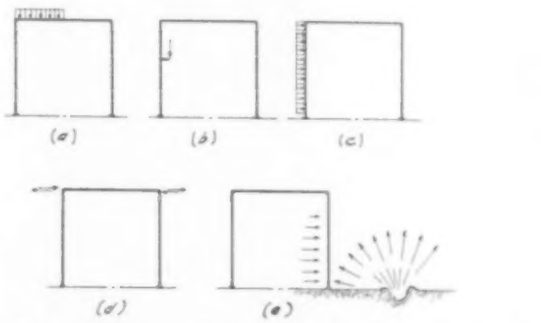


Fig. 3 - Conditions of Loading Requiring Joint Rigidity: (a), Unsymmetrically placed; (b), Bracket; (c), Wind; (d), Earthquake; (e), Explosion

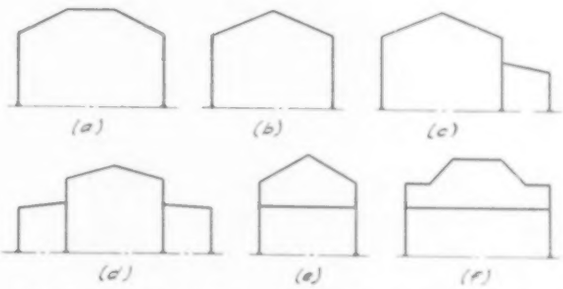


Fig. 4 - Cross-Sectional Outlines of Industrial Building Bents

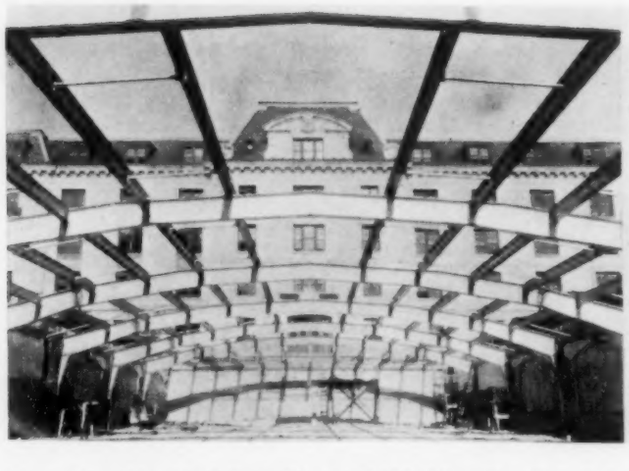


Fig. 5—Assembly of Arch Bents Prior to Field Welding, Mess Hall, U. S. Naval Academy

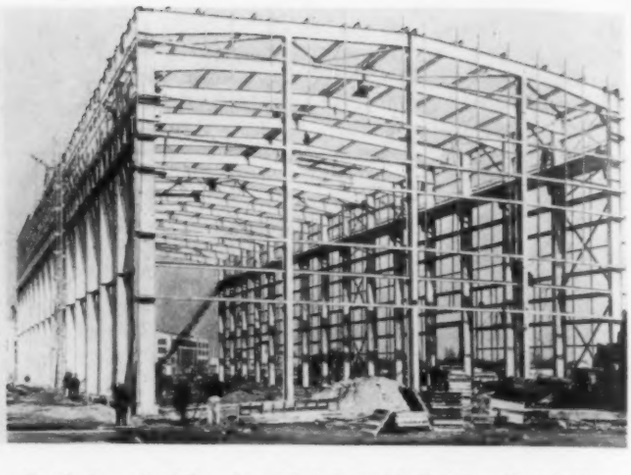


Fig. 7—Completed Framing of Sub-Assembly Building, Norfolk Navy Yard

fore, consider the case in (*b*) as the minimum condition of stability and rigidity; that is, if the members are to act together—and help each other—in resisting the action of the external force, at least the two top joints, which connect the three members together, should be rigid. Similarly, the bent in (*c*) presents the condition of maximum rigidity, resulting from rigid top joints and fully restrained bases. For comparison, the relative deflections and moments of the two bents are shown in Fig. 2. Assuming that the members are of equal stiffness, it is noted that the deflection of the bent with hinged bases is 4.2 times that of the bent with fixed bases; and that the moments in the struts and in the upper portions of the legs of the former are $2^1/_3$ times larger than the corresponding values in the latter bent.

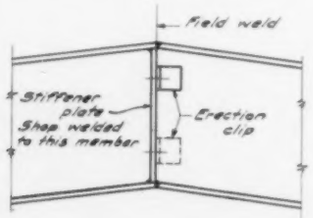


Fig. 6a - Detail of Field Splice Providing Direct Butt Connection Between Flanges.

CONDITIONS OF LOADING AND TYPES OF FRAMING

A properly designed frame combines advantages of both economy and rigidity. The relative importance of these factors is greatly influenced by the condition of loading to be carried and the outline of framing. In general, the importance and desirability of providing rigid connections in a building increases with the anticipated increase of relative displacements of its various joints under a given loading. Accordingly, it is far more important to have rigid connections in a two-legged bent, subjected to a system of lateral loading, than in a multi-bay framing of the tier-building type, which supports vertical loading.

Some of the conditions of loading, as encountered in most designs and requiring rigidly connected framing, are shown in Fig. 3. Here (*a*), (*b*) and (*c*), respectively, indicate the familiar forms of unsymmetrically placed vertical loading, bracket loading and wind loading; (*d*) is the earthquake loading—imposed by nature; and (*e*) is a new condition of loading, associated with blast and explosion, created by modern warfare.

Certain types of framing will need rigidly connected joints under all conditions of loading—regardless of the manner of application. These comprise the gable, arch and hip bents, commonly used in the framings of industrial buildings. The great majority of the Bureau's welded structures may be grouped in this class. Typical cross-sectional outlines of these buildings are shown in Fig. 4.

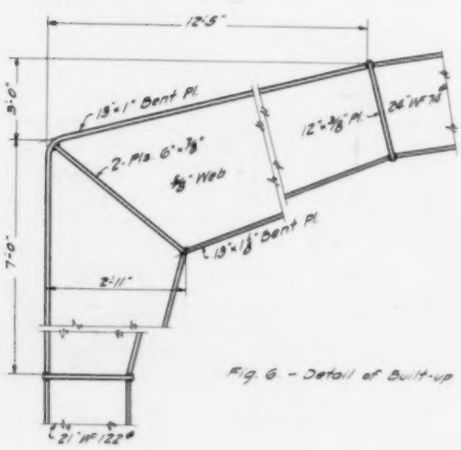


Fig. 6 - Detail of Built-up Knee

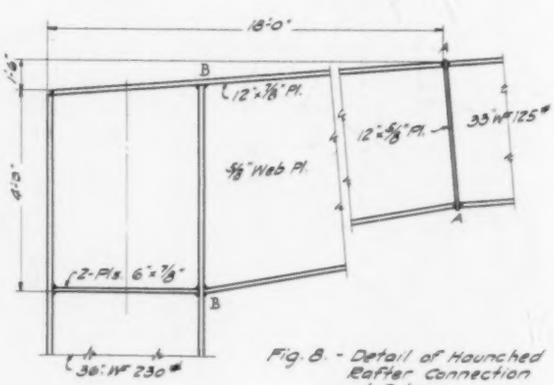


Fig. 8 - Detail of Haunched Rafter Connection at Column.

DETAILS OF FRAMING AND CONSTRUCTION

Representative of the arch-bent type, Fig. 5 illustrates the Bureau's first all-welded rigid-frame construction. Being an alteration project, the steel bent replaces an old three-span concrete groin arch, with obvious advantages of improved appearance as well as rigidity. The bents have a span of 75 feet, with a height at the crown of 18 feet, and are spaced 25 feet on centers longitudinally. In order not to impose additional strains upon the existing pile-supported piers, the columns are provided with unrestrained connections at the bases, and underground tie rods insure against spread resulting from lateral thrust. Except the knee section, all members of the bent are made of rolled wide-flange beams. The knee, shown in Fig. 6, has a single-piece web plate with corner stiffeners and bent-plate top and bottom flanges. Of the seven joints of the bent, the two joints next to the crown were welded in the shop; the crown joint and the connection between the knees and the columns were welded on the ground before erection, and only two joints—those located in the zones of minimum flexural stresses—were field welded in place. All the joints are of butt-plate type, webs and flanges of the members being, respectively, fillet and butt welded to the through-stiffener plates. This arrangement of splice, adopted primarily for field connections, with a view of facilitating assembly and alignment of adjoining members during erection, has been modified in the latest design of the Bureau by limiting the depth of the stiffener plate to the distance between the two flanges of the beam. The new detail, shown in Fig. 6 (*a*), provides direct butt connection between the adjoining flanges and eliminates the danger of weld failure on the tension side of the connection because of the possibility of plate lamination.

As an example of the gable bent, Fig. 7 shows the framing of a typical shop building. The building is 604 feet long, and the bents—spaced 20 feet on centers—have a span of 100 feet with a height at the center joint of 69 feet. Due to the rather small roof slope—just adequate for drainage—it may also serve to illustrate the case of a simple rectangular bent. The roof rafters are composed of two built-up knees at the ends and two rolled wide-flange beams at the middle portion. The knee section, sketched in Fig. 8, is 15 feet long and 4 feet 3 inches deep at the outer end, its upper flange extending over the top of the column. Similar to the framing in Fig. 5, the joints have butt-plate arrangement. Welded brackets for 40-ton bridge crane, semi-restrained column base connections, underground tie rods and pile-supported piers complete the main features of construction. The contractor's choice of field welding sequence consisted of the following: first, joints *A* (Fig. 8), located in the zones of minimum stress under gravity loading, were welded on the ground; then, after placing the two rafter sections in position, the joints *B*—connecting the knees to the columns—and the crown joint were welded in that order. As a result of this rather unusual procedure of welding joints under maximum stress last, certain closure difficulties were encountered in some of the bents.

Fig. 9—Partial Assembly of Framing, Addition to Shipfitters Shop, Portsmouth (N. H.), Navy Yard

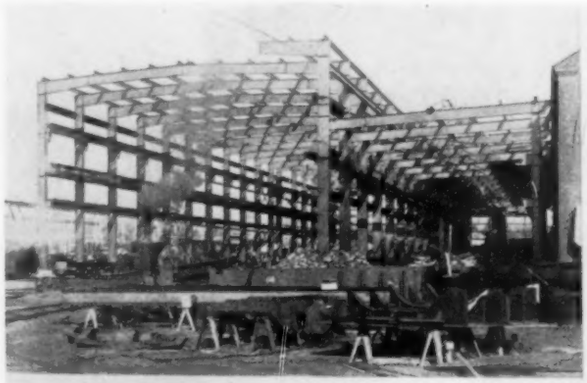


Fig. 10—Partial Assembly of Framing, Extension Structural Shop, Boston Navy Yard

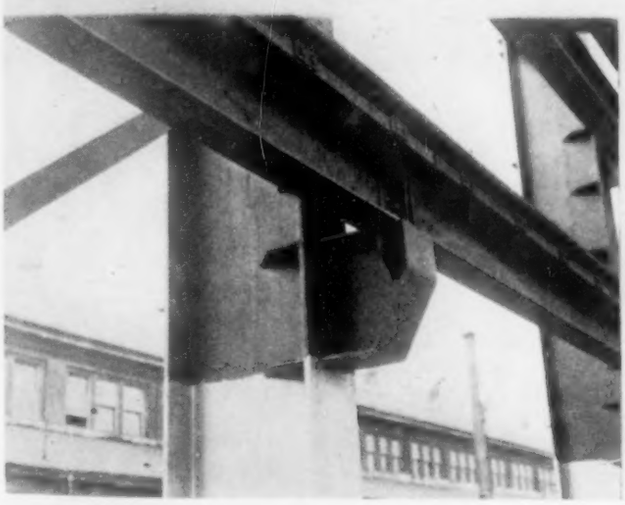


Fig. 11—Detail of Typical Crane Bracket, Extension to Structural Shop, Boston Navy Yard

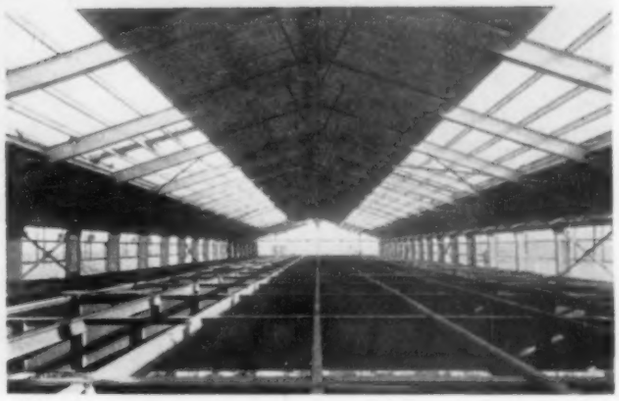


Fig. 12—Interior View of Mold Loft, Showing Gable Roof Framing, Extension to Structural Shop, Boston Navy Yard

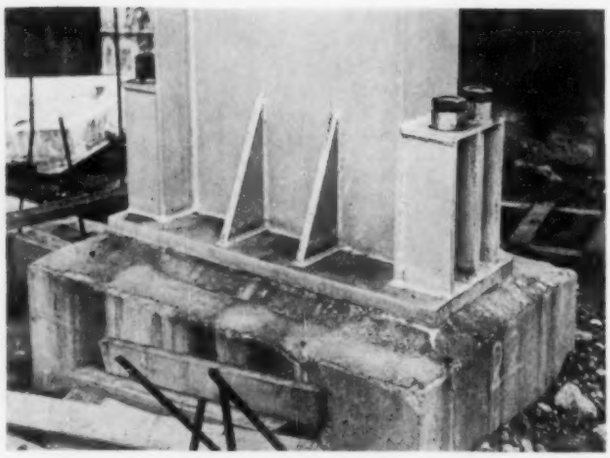


Fig. 13—Detail at Column Base, Extension to Structural Shop, Boston Navy Yard

Figure 9 is an example of the lean-to gable bent. The span of the main bent is 100 feet and the height 56 feet. The building is 432 feet long and the bents are spaced 23 feet 4 inches on centers. In addition to the brackets for a 50-ton bridge crane, the columns have welded supports for 6-ton wall cranes. Other details are similar to the framing in Fig. 7, as described above, except that a more logical sequence of welding was adopted in the field, namely: the knee sections were welded to the columns on the ground, as were the center joints of the rafters; after the columns were erected and the rafters lowered in position, the remaining two joints of each bent were welded in place.

Figure 10 illustrates a two-story gable bent. Of rather unusual proportions for its type—the building is 400 feet long, about 100 feet wide and 80 feet high—it combines a first-story shop—with a clear height of 46 feet—and a second-story mold loft. The high gable, required for proper lighting at a desirable angle, adds to the arch effect in the upper portion of the bent and results in the use of slender rafter sections—in this case being 24-inch wide-flange beams. The built-up knees in the second story, the column brackets (Fig. 11), as well as the entire bent, present decidedly streamlined appearance, thus adding esthetic advantages to the economy of design. The floor girders are 54 inches deep, having one-piece web plates and butt-spliced flanges. Despite the shallow depth, the maximum computed deflection of the girders, under dead and 80-lb. per sq. ft. live loading, is only 2.3 inches, or $^1/_{520}$ of the span; the obvious stiffness being traceable to the rigidity of the end connections. Figure 12 shows the interior view of the second story and Fig. 13 gives the detail of anchorage at the column bases, which in this instance are located above the floor line and exposed; accordingly, the underground tie rods are anchored directly into the foundation piers. The erection sequence is evident from the partial assembly of the bents in Fig. 10.

PROBLEMS IN DESIGN

Continuity.—For the field connections of the secondary framing, such as girts, struts and bracings, the contractor is generally given the option of either welding or riveting. In the case of purlins, until recently no attempt was made to provide continuity, since it was felt that the savings resulting from 33% reduction in moments by butt-connected continuity would, to a large extent, be offset by the added expense of welding. However, a new method of splicing, consisting in lapping channel purlins—placed back to back—over the supports, as shown in Fig. 14, and thus resulting in theoretical reductions in weight as high as 57%, has made continuity a desirable feature which is now being incorporated in the design of the latest structures of the Bureau.

Fixity at the Bases.—Since restraint at the bases depends upon rigidity of the connections as well as the support condition of the piers, the proper degree of fixity to be adopted in a design must accordingly be based on judgment. The structures described above are supported on foundations of vertical pile clusters, representing a case where some eventual rotations might be expected. For this reason, the condition of restraint at the bases was assumed to be halfway between that of a fixed and hinged connection.

Permissible Unit Stresses.—In a rigid-frame bent little distinction can be made between a column and a beam, since both members carry flexural as well as axial stresses.

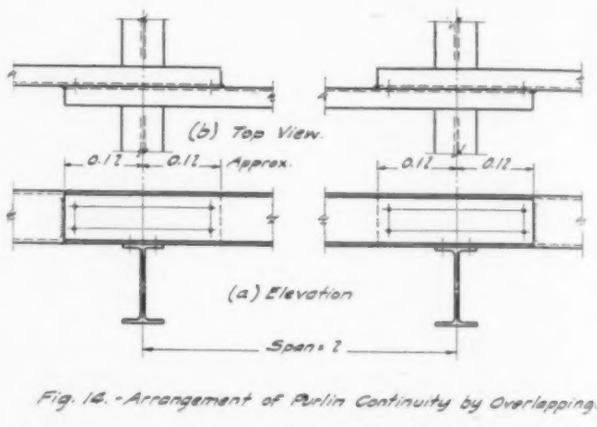


Fig. 14.—Arrangement of Purlin Continuity by Overlapping.

The former constituting the larger percentage of the resultant stress, the same limiting unit stress—governed primarily by the elastic stability of the compression flange—must accordingly be used in proportioning the sections of both members. With this concept, in the design of the forementioned framings, no reductions from the basic stresses were deemed necessary.

Method of Analysis.—A welded rigid frame is inherently an elastic structure, behaving as an elastic unity. The importance of a careful analysis—under various conditions of loading, including the effect of probable settlement and spread of foundations—cannot be overemphasized. The Bureau's method of analysis is based on slope deflection, considered as the simplest and most general method of attack for the solution of stresses in statically indeterminate structures.

ACKNOWLEDGMENT

The increased and successful use of welding is dependent to a great extent upon progressive leadership. Indeed, technique alone can make little headway without the aid and encouragement of those in charge of organizations for providing opportunities of application. In this, the Bureau of Yards and Docks of the Navy Department is most fortunate; for its Chief, Rear Admiral Ben Moreell (CEC), U. S. N., himself is a pioneer in the field of continuous structures, and the Design Manager, Commander C. A. Trexel (CEC), U. S. N., a great advocate of welding and member of various code committees of the A. W. S., is the originator of the present extensive welding program.

RESISTANCE FLASH WELDING OF Strip in Steel Mills*

By J. H. COOPER†

GENERAL

FACED with the gradually increasing speeds of continuous pickling lines and the ever-present striving for highest efficiency and quality from the cold reduction rolls, steel mills are realizing to a greater extent than ever before the advantages to be gained by welding single into multiple coils. Major advantages are the elimination of much lost time in threading smaller coils through various processes of the steel mill; the minimizing of the percentage of "off-gage" and scrap steel coming from the cold-reduction line and the meeting of customers' demands for larger and longer coils.

The steel mill processes such as pickling, recoiling, rolling and shearing have been so increased in operating speeds by modernized equipment that the time used for threading short coils has become a greater percentage of the total time than ever before. The present limitations of billet sizes for hot rolling to produce high-quality steel and the necessity to obtain wide strip from these billets have resulted in relatively short coils. The investment charges on machines and labor resulting from a high percentage of "threading" to "running" time warrants due consideration of the welding of coils.

Increased speeds of cold reduction mills have caused higher percentages of "off-gage" strip while the mill is accelerating and decelerating. Modernizing previous practice by the use of three- and five-stand reduction rolls has lengthened the amount of "off-gage" strip at each end. More strict customer specifications as to uniformity of gage as well as requests for longer, heavier coils have played their part in the adoption of welding.

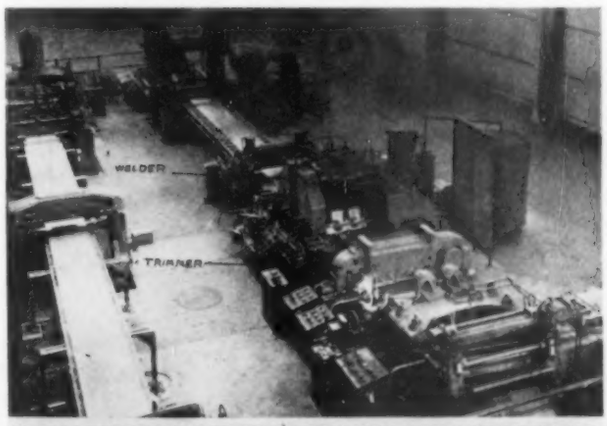
With the necessity for the use of welding came the necessity for selecting the process and equipment. The factors which determined the necessity of welding again largely determined the process and type of equipment. These factors are high production, best of quality and low maintenance cost of machinery with no increase of unit labor cost due to requirements of a higher degree of manual skill. Concerning production, the resistance flash welder will hold its own against any other process. Jigging or clamping for any process will run approximately the same and the actual welding time of 5 to 20 seconds depending on stock gage is difficult to improve.

As to quality in an application where the weld must approach very closely the characteristics of the strip without varying in uniformity and undergo the deformation of cold reduction, it may be unreservedly stated that resistance flash welding is superior to all other processes commercially practicable. Operators may quite readily be obtained to make such flash welds. Often after a short period of coaching they need no further instruction, nor ever require a high degree of manual skill. The fact that the weld quality no longer depends on the human element of welding as it does in any hand process, is a source of no small degree of satisfaction to an operating management. Machine maintenance is kept to a very minimum by specialized welder design for steel mills. Other than a periodic dressing of dies, normal machine greasing and maintenance is sufficient.

APPLICATION IN A PICKLING LINE

As in the application of any other specialized equipment, proper consideration must be given to the specific problem. Flash welders are in operation in pickle lines, cold-reduction lines and recoiling lines. Some welded strip is sheet steel and some is tin-plate stock. Some welds are cold reduced and some are not. Figure 1 shows an installation for welding strip for tin plate. Figure 2 illustrates an installation for welding strip for

Fig. 1—Resistance Flash Welder with Hydraulic Controls Installed in a Continuous Pickling Line. Welder Is Capable of Joining Steel Strip to a Maximum Section of 3/16 x 40 Inches and Majority of Strip Is Cold Reduced to Tin-Plate Stock



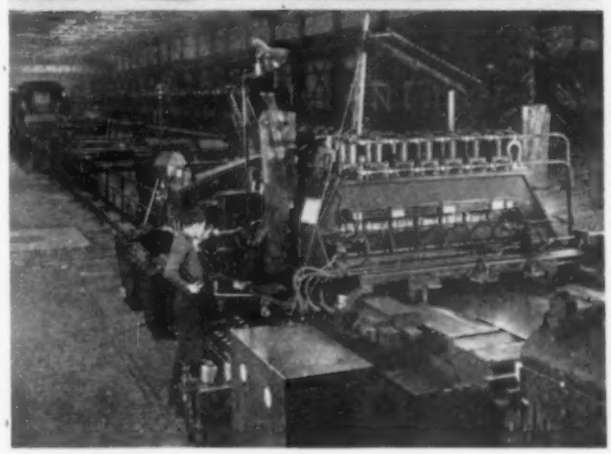


Fig. 2—Actual Flashing Taking Place in Hydraulic Flash Welder Installed in Continuous Pickling Line. The Majority of the Strip Passing Through This Line Is Cold Reduced to Sheet Thicknesses and 1/8 x 80 Inches Is the Maximum Section Welded

* To be presented at Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Welding Engineer, The Taylor-Winfield Corp., Warren, Ohio.

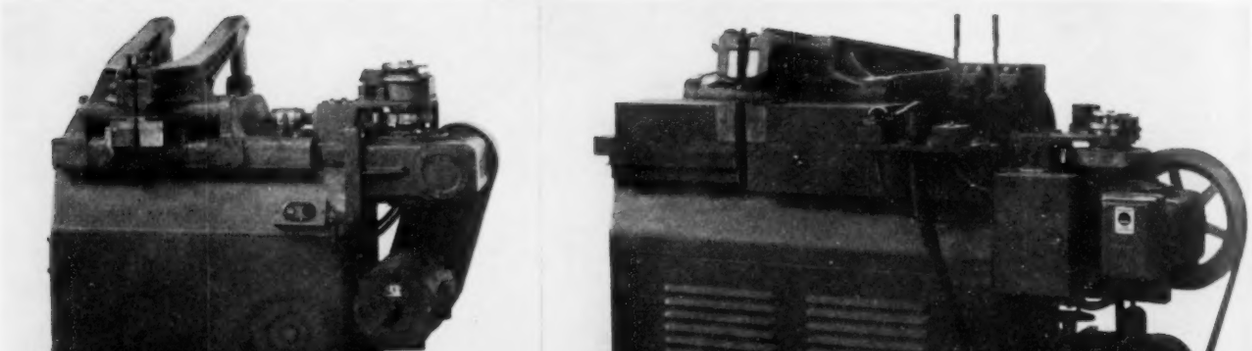


Fig. 3—(*A*) Small Size of Motor-Operated Welder Capable of Welding 1/8 x 4-Inch Maximum Strip Section Is Used Principally for Joining Strip for Continuous Processes and for Making Larger Multiple Coils for Automotive Industry. (*B*) Medium Size of Motor-Operated Welder Capable of Welding 3/16 x 8-Inch Strip Section and Is Also Used Principally for Joining Strip for Continuous Processes and Making Multiple Coils

sheet. A description of a welder in a continuous pickling line where the pickled strip is subsequently cold reduced will serve as an illustration. Such a description will by necessity include allied equipment in the line.

The coiled strip from the hot mill is fed into a combination uncoiler and processer. This processer straightens the strip and partially breaks up the scale on the strip. This straightening is an aid in obtaining proper vertical alignment of strip at the weld. If the processer is not adjusted properly to take out the coil curvature the "spring" in the strip will bend the soft red hot metal of the weld during transfer from welder to trimmer and increase trimming difficulties. The breaking up of heavy scale assists in keeping down welder die maintenance as heavy scale tends to cause "die-burns" of the current conducting dies. In the ordinary run of scale on processed strip the dies may not require redressing for several months. The strip proceeds from the processer to the shear where the "head-end fish-tails" are cropped off.

Time used in shearing up these croppings into scrap varies with the quality of steel coming from the hot mill; that is, how accurate the hot strip has been cropped at the hot mill as to length to obtain uniform width and quality. To meet welding requirements the shear has only to make a good clean cut. If it is a properly designed and well-maintained shear the cuts will be clean with no rolled-over edges. It is obvious that if a shear puts a crimp in the strip near the cut edge, the problem of proper vertical alignment of the strip at the weld becomes more difficult. The question of shearing square or on the bias is one which must be determined by the choice of welding equipment and the particular application at hand. This point will be discussed further in this article. It suffices to say that sometimes it is necessary while at other times it results in unnecessary lost time and increased expense. In all cases the strip should be properly located for the shearing cut by adequate side guides. This is necessary so that either the square or bias cut may be duplicated in proper position when advanced to the welder. The strip guides locating the strip ends for welding must so locate the strip that after welding it has no camber due to welding, and so locate strip ends that any excessive width of one end over the end to be welded to it is equally divided on both sides. After the weld is made it passes in turn through the flash trimmer, stitcher, looping pit and rest of the pickle line to emerge as a double, triple, etc., coil depending on the number of short coils welded. The coil ends as delivered to the welder vary both in thickness and width. A number of measurements on good hot strip in one installation indicated that the head end of the strip at the welder (the tail end off the hot mill) averaged 0.066 inch while the tail end averaged 0.062 inch. The head end (hot mill tail end) also averaged 5/8 inch wider than the tail end when welding 55-inch wide strip. The welder and trimmer dies must be so designed as to equalize pressure on the variable thicknesses. Unequal strip widths at the weld do not affect the weld and are primarily a nuisance only if overhanging corners catch on strip guides. In some installations the corners are notched out in the shape of small "half-moons" with a nibbler or shear. In other cases the weld is cold reduced without being touched. In at least two installations the width variation at the weld is corrected when the strip is side trimmed for its full length.

The strip should at all times be quickly and accurately centered by proper side guides. It is recommended that guide shoes be hard surfaced at wearing areas as the grooves worn in soft shoes by the strip edges destroy accuracy of alignment. The application of a welder in the pickle line, for instance, should be carefully engineered to the end of accomplishing the preparation of strip ends, welding and trimming in the very minimum of time. In continuous production, the time permissible for these three operations is the differential between the time required to pickle a given amount of strip and the time required to run a like amount into the "looping pit." Let us presume we are pickling 500-foot coils at an average rate of 150 feet per minute. This required 3.33 minutes per coil to draw the coil out of the looping pit and pickle it. Also we run the following coil into the pit at an average rate of 400 feet per minute. This requires 1.11 minutes. The differential, or 2.22 minutes, is the time available for shearing, welding and trimming in order to keep the line in continuous production. With pickling speeds being gradually boosted by advances in that art, the speeding up of the shearing, welding and trimming is requiring more and more thought and ingenuity. When comparing welding speeds with stitching, it must be remembered that the time required for

stitching subtracted from the time of welding and trimming is the true differential, as the ends of the coils must be sheared in both cases. The looping pit, between the uncoiler, welder, trimmer, stitcher and stitcher pinch rolls on the entry end and the pickling tanks on the exit end, provides sufficient storage of strip that the pickling may proceed continuously although the incoming strip stops for each weld or stitch. In some cases the pit is filled with water to wet the strips before pickling and to help prevent scratching of the strip surface.

The selection of the strip welder is governed by the application. Consideration must be given to the range of strip cross-sectional area to be welded as well as to the frequency of changes in area to be made in production. If we analyze the requirements of a welder in terms of what takes place at the weld, we may list the following factors: (1) a proper start of the flashing action; (2) the "flashing-off" or burning away of a sufficient amount of metal for the particular gage of strip under consideration at an optimum rate and optimum welding voltage and current; (3) a speedy and powerful "upset" or forging action of proper magnitude. Figure 3 (*A*) shows a very common type of motor-operated welder which will handle strip up to a maximum section of $^1/_8$ x 4 inches. This type of welder has been quite successful in the automotive field and has operated in production in this field at a rate as high as 600 welds per hour. Figure 3 (*B*) shows a motor-operated welder with air clamps which will handle strip up to a maximum section of $^3/_{16}$ x 8 inches.

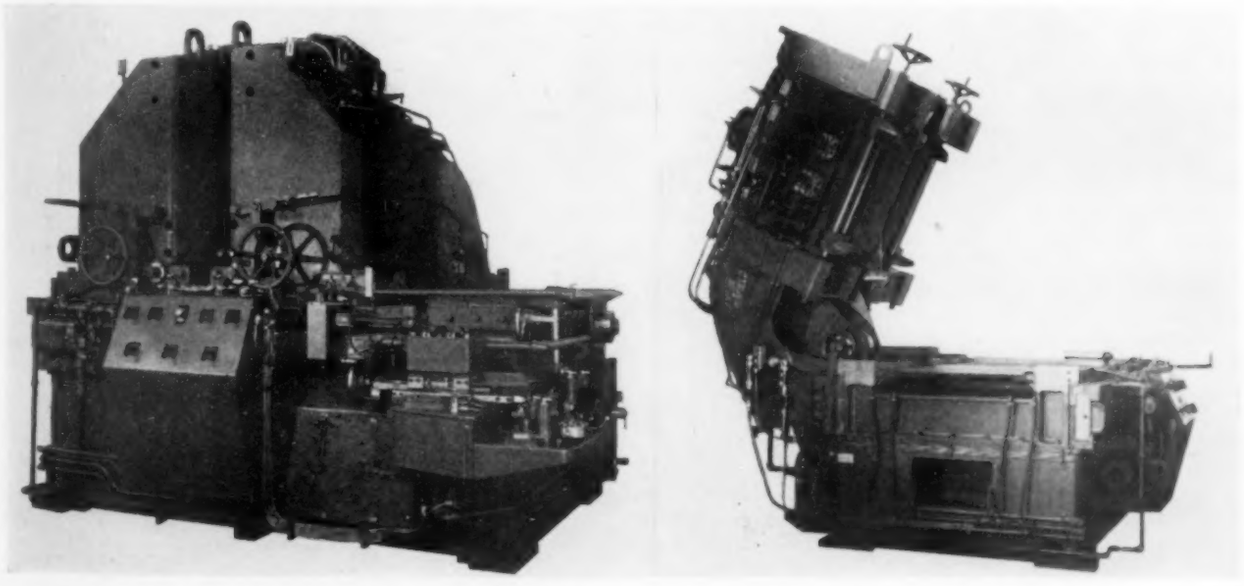
The motor-operated type of welder built in this country is almost universally irreversible in sequence; i.e., once the machine cycle is started, the motor, through a gear reduction and cam, pushes the ends of the strip together, flashes off an amount as determined by the cam and upsets the ends together by means of a bump on the cam. It is this irreversible feature which dictates in many cases that the strip ends be sheared on the bias to offer point contact and facilitate easy starting of the flashing arc. The amount of material flashed off is determined by the rise in the cam from the starting to the upset points. These cams must be very carefully generated to a shape as dictated by the flashing rate of the section welded at a given speed, current and voltage. In apparatus handling heavy sections these cams must be quite massive so as to transmit high upset pressures properly. The upset bump is generally a hardened insert set in the cam at the proper place and shimmed to sufficient height to give the correct dimension of upset required for the section welded. Speed of flashing is variable within limits by means of adjustable pulleys or gearing.

A factor which should be kept in mind when selecting a proper drive for a flash welder is the speed of upset. This should always be as fast as possible. The motor-driven type of welder, by its very nature, slows down the speed of upset as the rotational speed of the cam is reduced when lengthening flashing time. In many applications this change of upset speed is not of great importance as welds are not subjected to great strain. In other cases it is of importance to obtain highest quality welds. The hydraulic type of control has speed of upset always at its maximum and independent of speed of flashing. Operating departments familiar with flash welds notice this difference as manifested by a larger swelling of upset metal when using motor drives and consequent greater maintenance of trimmer knives. Welding voltage is usually adjusted by means of taps in the welding transformer primary.

Figure 4 presents a view of a hydraulic type of welder designed specifically for steel mill strip welding. Essentially such a welder has a movable slide or platen actuated by one or more hydraulic cylinders. One end of a coil of strip is clamped on the stationary die and the matching end to be welded to it is clamped on the movable die. A hydraulic pumping unit delivers high-pressure oil to the actuating cylinder to cause the slide to move a controlled dimension at a controlled variable rate. The heart of this type of welder is the valving mechanism controlling the oil to the slide cylinder. The valve proper permits very sensitive control of the cylinder oil through poppets. This valve is actuated by a lever which first brings the projecting strip edges in just enough contact to start proper flashing and, second, moves the slide at a predetermined adjustable rate and adjustable dimension by means of an automatic line cam. The action is reversible at any time and is so used to get a proper flashing start

Fig. 4—Close-Up of Front View of Type of Welder Shown in Fig. 1. This Hydraulically Operated Welder Is Specifically Designed for Steel-Mill Service with Quickly Changeable, Readily Accessible Controls and Will Handle a Range of Strip Sizes from 0.050 x 5 Inches to $^3/_{16}$ x 40 Inches. Welds Made by This Welder Can Be Cold Reduced to Tin-Plate Thicknesses of 0.009 to 0.012 Inch

Fig. 5—Side View of Welder Shown in Fig. 4 with Clamping Fixtures Elevated to Permit Ready Access to Welder Dies or to Give Greater Strip Clearances in Line When Welder Is Not Used



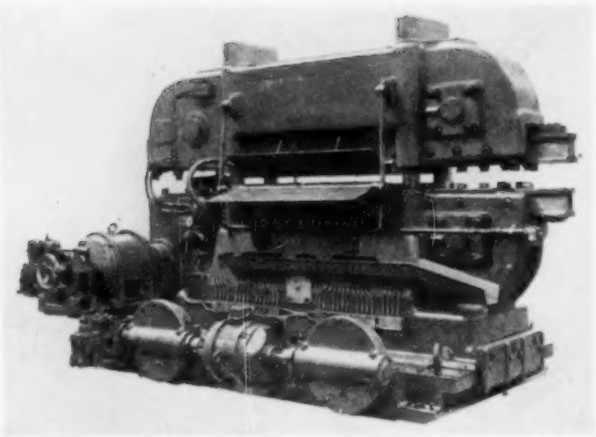


Fig. 6—Heavy-Duty Steel-Mill Type of Automati Weld Flash Trimmer. Trimmer Works on Shaper Principle with Five Trimmer Knives Adjustable in Upper and Lower Nitralloy Rams. Also Is Motor Driven with Horizontal Traverse, Equalizing Clamping and Fully Automatic Operating Cycle

if necessary. Strip edges may contact squarely or otherwise, it matters little. No special precaution of bias shearing is required nor is there the danger of the starting arc "stumbling" or "plugging." Inasmuch as strip welding of mixed production requires a machine capable of rapid changes over a wide range of welded sections, the hydraulic type is particularly adaptable. The welder shown in Fig. 4 will weld from $^{3}/_{16}$ x 40-inch sections to 0.050 x 5-inch sections.

The speed of flashing may be varied by a calibrated vernier needle valve from 4 to 40 seconds. The amount of metal flashed off is readily controlled by a small line cam adjusted with a micrometer screw. This eliminates the changing of bulky rotary cams of variable shape. The amount of upset is controllable over a wide range by means of a calibrated hand wheel. The speed of upset is of the order of 400 inches per minute. Such a high speed is obtained by throwing open the control valve automatically and absorbing the full output of an air-operated oil accumulator. Two auxiliary controls determine the amount of strip initially projecting from the dies and the final closed die dimension. A rotary regulator permits selection of proper secondary voltage through a tapped transformer primary. Hydraulic pressure regulators vary clamping pressure for varying strip dimensions on strip. A complete change of controls can be made within 90 seconds. Presuming the ends of the strip are sheared, the weld may be made and trimmed in approximately 90 seconds. For ease of maintenance of dies, the entire superstructure may be thrown back with a crane to grind the dies in place with a portable grinding outfit or to change them. Figure 5 shows the superstructure so thrown back. The welder and trimmer bench boards should have strip controls providing inching speeds to accurately locate the strip ends or weld in the welder and trimmer.

The trimming of the weld flash may be done by several designs of trimmer with varying degrees of success. A quality trimmer is one which consistently trims the flash off from about 0.002 inch above to 0.002 inch below the surface of the strip. Uniformity of trim is important as a trimmer which does not follow the strip variations will trim either too high or too low, and so result in a poor weld for cold reduction.

The best weld is obtained when the trimmed surface is flush with the strip surface or slightly below the surface. Reasons for this are threefold:

1. It is important that the hard flash above the surface be removed because it is detrimental to the highly polished surface of the cold-reduction rolls.

2. The hard flash above the surface is forced down into the relatively ductile strip section during cold rolling and has a tendency to "pinch" the strip and cause a fracture.

3. The material above the surface acts as a "bump" for the rolls to strike and so cause several feet of off-gage strip and throw an unnecessary strain on strip and weld. In some cases attempts have been made to overcome this trouble by slowing down the cold-reduction mill momentarily when the weld passes through. This in itself creates some off-gage material. It is not necessary if welds are properly trimmed.

Many welds trimmed slightly below the strip surface have been cold reduced in production with the mill running at full speed. Contrary to first thought, the strength of the section is not reduced below that of the rest of the strip. The slight increase of weld hardness over strip hardness is accompanied by an increase of tensile strength and competent metallurgists claim the welded section of a properly made weld could be reduced to 90% of the strip thickness and still have a strength equal to the rest of the strip.

The more quickly the weld is trimmed the more smooth the surface will be after trimming. This is because the metal is cut red hot. The trimmer should be located as close to the welder as possible and controls arranged to facilitate this trimming as quickly as possible after welding. Trimming dry is preferred with stellite tipped cutters. This also avoids rapid removal of heat from the weld by the use of a cutting lubricant.

For best production, the automatic type of trimmer which clamps the strip, trims and unclamps in an automatic sequence is to be preferred. Both hydraulically and mechanically operated trimmers give good results. An equalizing set of clamps which compensate for the variations of strip thickness from one side of the weld to the other is of distinct advantage. Not only does it make a more uniform trim but bevels the weld from the thick to thin strip. Figure 6 shows a typical mechanically operated trimmer as furnished for the installation shown in Fig. 1.

WELD CHARACTERISTICS

A typical question is how good is the weld and how do welder variables affect it? The final answer in most installations as to quality lies in the capability of the weld to undergo cold reduction. Sometimes this means re-

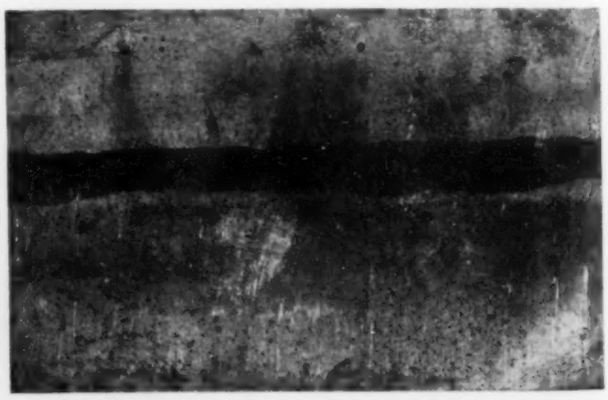


Fig. 7—This Photo Shows the Surface Appearance of 0.062-Inch Strip Welded, Trimmed and Cold Rolled to 0.018 Inch in Thickness. Scale Is About Half Size. The Sheet Is Perfectly Smooth but the Dark Area in the Photo Is Caused by the High Lights Which Remain Through the Rolling Operation Due to the Trimmer Marks on the Welded Strip Surface

duction to sheet stock and sometimes to tin-plate stock. A typical reduction for tin plate is cold rolling from 0.076 inch thickness to 0.009 inch or 0.010 inch in a single-stand reversing or 5-stand tandem mill. Figure 7 shows the appearance of a rolled weld. All measurements of hardness, tensile strength, ductility, etc., may be used as yardsticks of comparison if properly interpreted. In the following discussion of weld characteristics it should be noted that we refer to very low carbon (approximately 0.06%, 0.30% manganese) *A*-1, deep-drawing strip steel just off the hot mill. Higher carbon content, high silicon alloys, heat treatment, etc., changes the whole picture of welding technique and weld characteristics.

Let us consider first weld hardness since the question of "soft-welds" is always brought up. It is necessary to have a definite method of making hardness tests before an adequate comparison can be made. To take a trimmed weld cut out of the strip and run a hardness test on the surface of the trimmed upset is misleading. The weld and the parent metal near the weld should be polished and all metal cleaned of any scale. The weld surface and the strip surface for at least an inch each side of the weld should be prepared for etching. A light macro-etch using any typical etchant such as a 10% solution of ammonium persulphate should be used to bring out the weld line. In many cases the hardest zone, which is the true weld, is only about 0.010 to 0.030 inch wide. The greater the speed of upset, the narrower will be the hardened zone. This section is quenched from the highest temperature and most affected by the forging action of the upset. To check for the hardest point of the weld without preparing the surface and etching is to risk overlooking the hardest zone. Even when etched, the brale of the Rockwell tester (if used) must be centered squarely on this hard zone. Otherwise it may slip off to the side and indicate a softer metal than the maximum hardness. It is relatively easy to obtain soft welds at any place in the section except in this narrow zone. It is this zone which is most sensitive to proper welding technique. Table 1 indicates hardnesses and differential of hardness of welds made in production in six separate steel mills using welding equipment manufactured by three different prominent manufacturers. The gages of the strips were all about the same, 0.095 to 0.115 inch. The figures represent points of hardness, Rockwell B scale, "as-welded" and before cold reducing.

Table 1

Installation	*A*	*B*	*C*	*D*	*E*	*F*
Weld	82	71	73	76	91	72.5
Strip	*72*	*58*	*55*	*55*	*60*	*58.0*
Differential	10	13	18	21	31	14.5

These figures show there is a wide variation in both weld hardness and hardness differential. After a great many tests were made, a technique of welding was developed which keeps this differential down to 10 to 15 points above the hardness of this strip material (see Table. 2). It is questionable that this material may

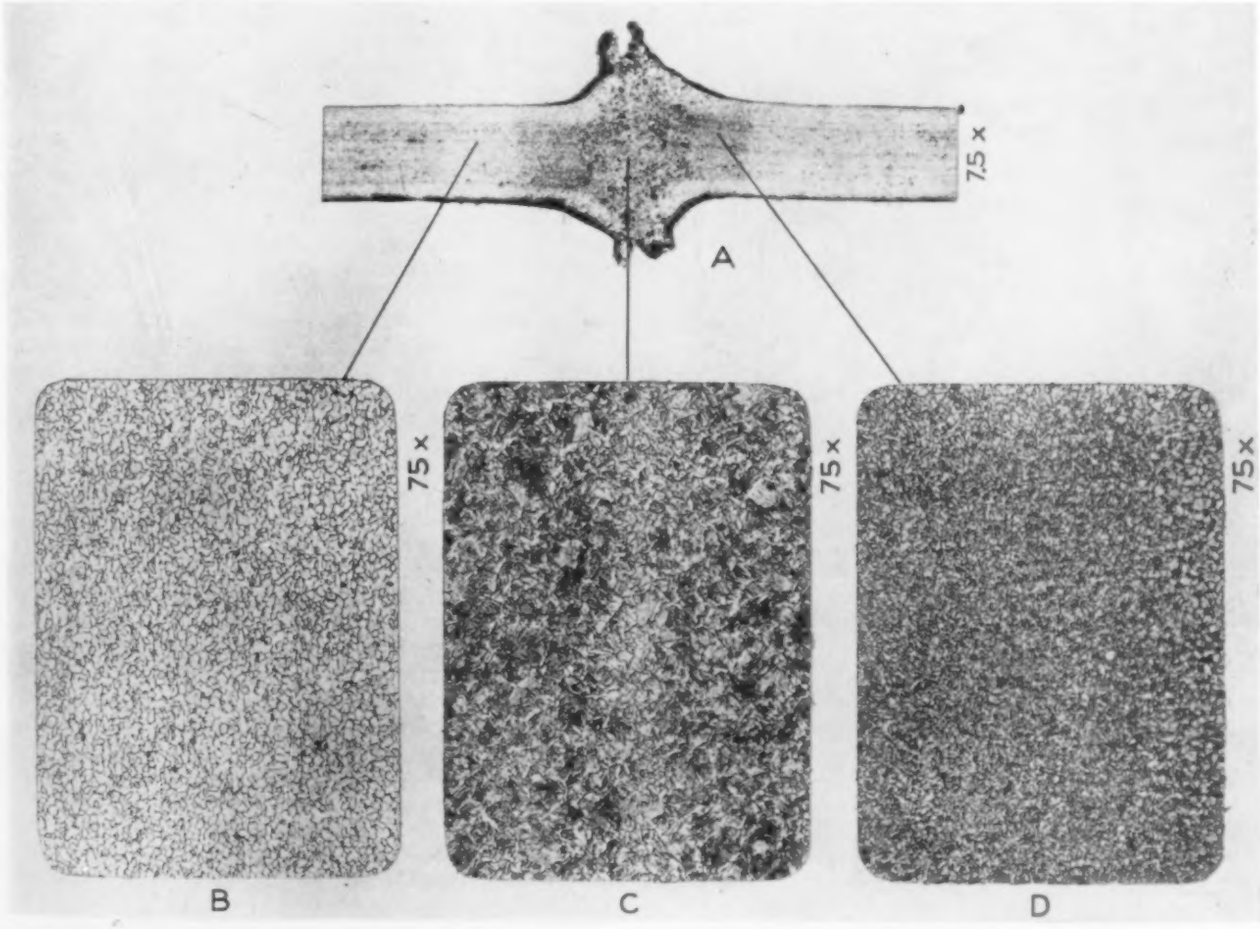


Fig. 8—*A* Is a Photomacrograph of a Resistance Flash Weld in 0.076 Inch Thick, 0.06% Carbon, 30% Manganese, *A*-1 Hot-Rolled Deep-Drawing Steel Etched with 3% Nital and Taken at 7.5 Diameters. *B* Is a Photomicrograph of the Original Parent Strip Etched with 3% Nital and Taken at 75 Diameters. *C* Shows the Exact Center of the Weld and the Structure of the Zone Subjected to Highest Temperatures, Most Rapid Rate of Quench and Most Drastic Forging. Also Etched with 3% Nital and Taken at 75 Diameters Magnification. *D* Shows the Structure of the Heat-Affected Zone with Its Refined Grains. Also Taken at 75 Diameters and 3% Nital Etch

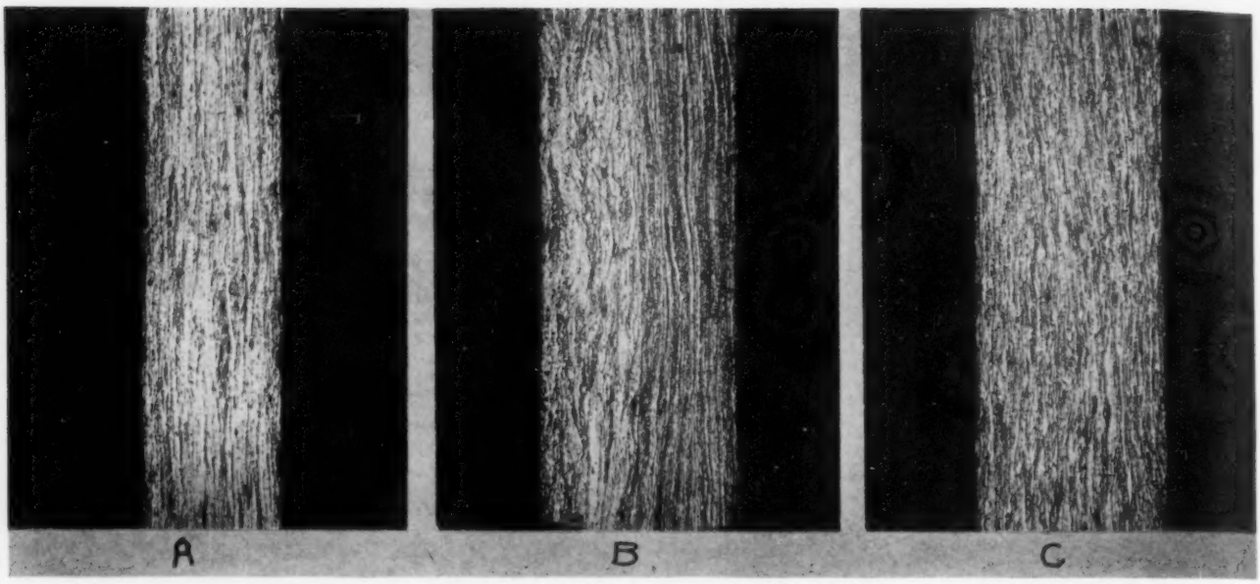


Fig. 9—These Photomicrographs Are Made of the Weld as Shown in Fig. 8 After Cold Reduction to 0.0096-Inch Thickness. *A* is the Parent Strip, *B* the Center of the Weld and *C* the Heat-Affected Zone. Magnification Is 75 Diameters and Etchant Was a Nitric Acid Solution in Absolute Methanol

be flash welded and a lower differential obtained without a corrective heat treatment after welding. Cold-rolling work hardens both welds and strip but hardens the weld to a lesser degree than the strip. For example, 0.076-inch strip rolled to 0.010 inch by five passes of a reversing mill will indicate a strip hardness of 96 and a weld hardness of 100, Rockwell B.

Table 2—Hardness Differential of Weld Center and Strip

Strip Thickness, Inches	Hardness Rockwell B at Various Dimensions from Weld Center: 0	$\frac{1}{16}$ In.	$\frac{1}{8}$ In.	$\frac{1}{4}$ In.	$\frac{1}{2}$ In.	1 In.	Weld and Strip Differential
0.053	76.5	71.0	69.0	65.0	64.3	62.7	13.8
0.117	71.0	69.2	64.8	62.3	57.6	57.5	13.5
0.180	87.5	84.9	80.8	75.5	75.3	74.2	13.3

The theory back of the technique is simple enough, its application being slightly more complicated. Any steel even as low carbon as 0.06% will harden somewhat if quenched fast enough. In a flash weld the quenching medium is primarily the cold metal adjacent to the heated zone. The steepness of the temperature gradient in the steel from the molten edges at the time of upset determines the degree of hardening. The chilling effect of the cold bronze or copper dies clamping the strip adjacent to the weld makes this gradient steeper. One of the proper steps in obtaining the least hardening is to have the dimension from the weld center to the nearest die contact as great as possible. This cannot be carried too far as troubles experienced in keeping the strip edges in vertical alignment will more than offset troubles rising from harder welds. A figure of $\frac{5}{8}$ inch for final die opening or $\frac{5}{16}$ inch from weld center to either die is practical for 0.095-inch strip even for strip 60 or 70 inches wide. Increasing this final die dimension creates a greater mass of metal in which to store heat to lower the thermal gradient. A secondary necessary step in obtaining soft welds is to have the actual flashing take place over a long enough time that the greater mass of metal obtained as in the above may have time to absorb heat. While flashing, the heat must come from the resistance of the steel to current conduction and from heat generated at the arc between the two strip edges. The majority of the heat comes from these flashing edges and time must be allowed for proper thermal conduction of heat back into the exposed mass of metal. If the flashing time is so short that the welding process is over before such thermal flow can take place, the steep temperature gradient results in too rapid a quench of the molten edges when they are forged together. The above-discussed delaying the quenching of the metal through its critical temperatures is the predominating factor in keeping weld hardness to the minimum possible for the material under discussion. For 0.125-inch strip, if $\frac{3}{8}$ inch is to be flashed off of each strip end, the flashing rate should be about 2.5 inches per minute. This means about 19 seconds flashing time.

It is not to be inferred that $\frac{1}{8}$-inch material cannot be welded in less time than 19 seconds. Many welds can be and are made in 25% of this time in various industries. However, when conditions prevail as in steel mills where the strip is quite wide and so not always sheared consistently square, and the welds must undergo cold reduction to 10 to 25% of their original thickness, the best possible welds must be obtained. These results can best be achieved by a proper length of flashing time.

Delaying the cut-off of the current a few cycles after the forging takes place and the arc is extinguished is not as beneficial as proper preheating during the flashing period. Any subsequent annealing action by this delay of cut-off is of small benefit. It is standard technique to cut off the current after the molten edges are forged together. While flashing, the edges are scavenged of any slag inclusions or gas pockets and protected by a gaseous blanket formed by the combustion of the steel in air. To cut off the current before these protected edges get together and fuse, results in reduced weld quality due to gas or slag inclusions. To be on the safe side, particularly when using mechanical contactors, it is preferable to have the cut-off delayed a few cycles.

The speed of the upset is of the order of one or two cycles of 60-cycle frequency and should be this fast for highest quality. The amount of the upset should be such that any surface imperfections in the hot metal are squeezed above the strip level and later trimmed out. Note this feature as shown by weld, Fig. 10, and the

lack of it as shown by Fig. 11. About $^1/_8$ inch is a proper upset dimension for 0.095 strip. The pressure required to upset strip is not very important. Strip welders, in order to clamp the stock to prevent slipping, are usually so massive that a very strong pressure system is required to accelerate such a mass to a top speed of approximately 400 inches per minute. Sufficient energy for upsetting the metal may usually be derived from this moving mass without drawing much from the pressure system. This is far from being true when flash welding a compact section like a 1-inch diameter rod with a relatively lightweight moving die carrier. Even greater pressure is required for upsetting stainless steel than low-carbon steel, due to its greater compressive strength and narrower plastic range and low thermal conductivity. For strip a total clamping pressure about three times the total upset pressure keeps the dies from slipping on the strip during upset. Upset pressure required per square inch of welded area for this material is approximately 10,000 pounds.

METALLURGICAL CHARACTERISTICS

When resistance flash welds are examined from a metallurgical viewpoint they present a similarity to metallic arc welds. Examination of the weld under the microscope reveals structures indicative of steel exposed to heating and cooling at temperatures from room temperature to the temperature of an arc or approximately 6000 degrees absolute.

Flash-weld structures differ from metallic arc welds chiefly in that the various zones are narrower and some zones are subjected to hot forging. Figure 8 (*A*) shows a low magnification view of all affected zones. Figure 8 (*B*) shows original unaffected parent strip with a normal grain structure of pearlite and free ferrite grains.

Figure 8 (*D*) is representative of the zone which has been heated to various temperatures above the first critical temperature. Upon reaching the first critical temperature, the grain structure of the pearlite shown by Fig. 8 (*B*) recrystallizes to form a fine-grained austenite, the alpha iron changing to gamma iron. Of the original structure approximately 71% is free ferrite and it remains unchanged. The other 29% of original structure is pearlite and it changes as noted above. As the dimensions from the center of the weld gradually decrease, we find structures which indicate the material has been heated to higher and higher temperatures. As these temperatures increase, the free ferrite recrystallizes from alpha to gamma iron and is absorbed by the austenite. The recrystallized structure of gamma iron remains fine grained during this change because it is being disturbed and grain growth is being prevented by diffusion and recrystallization of the free ferrite.

Figure 8 (*C*) is representative of the zones which have been heated higher than the second critical. In the zones near the outer edges of Fig. 8 (*C*) all the alpha iron has been changed to gamma and gone into solid solution with the austenite. Grain growth sets in at the austenitic grain-coarsening temperature and produces the coarse grain structure shown by the photomicrograph. The zone in the middle of Fig. 8 (*C*) shows metal which has been subjected to heating above the third critical, hot forging and rapid quenching. This material is composed of an austenite of very low carbon which becomes a pseudomartensite of relatively high hardness. This checks our findings when making hardness tests of this zone.

Figure 9 shows the same weld as in Fig. 8 but cold reduced from 0.076 to 0.0096 inch. The grains are greatly elongated and represent a typical structure. After reduction, the structural difference between original strip and weld are not so marked as before reduction.

Figure 10 is of particular value for showing the amount of upset metal forced above the strip line to be trimmed off to remove surface defects. The jagged-appearing material on the top and bottom of the weld is metal and slag expelled during flashing.

Figure 11 shows a weld which was upset at too low a temperature and to an insufficient degree. *A* indicates a slag inclusion which was not properly forced out.

Figure 12 indicates the results of not properly trimming all flash down flush with the surface of the parent metal. In Fig. 12 (*A*), which was taken after the first cold-reduction pass, the flash on the surface is starting to "pinch-off" the soft strip steel beneath the flash. Since the flash is harder than the strip, the cold-reduction rolls simply crush it down into the more ductile parent and weld metal.

Figure 12 (*B*) is a section showing the degree to which this "pinching-off" has progressed after three passes through the reduction rolls. This weld is just about ready to break. These photographs again emphasize the necessity of a closely controlled trimming procedure.

TENSILE TESTS

Tensile tests made of coupons cut out of the strip with a section of the weld in the middle are often used to test the strength of the welded joint. Almost invariably these coupons break in the parent metal some distance away from the weld if the proper technique has been used in making the weld. In no sense of the word may it be considered that the fractures are due to any metallurgical damage done to the strip by the welding process. The fractures usually take place 1 to $1^1/_2$ inches from the weld, usually even outside the elongation mark and in material which is shown by macrophotograph to be original unheated strip. In Table 3 are test results made of welds in 0.052-, 0.115- and 0.180-inch strip stock. Five specimens were tested of each stock thickness with weld flash and upset ground down to original strip thickness. Five samples were also tested of each gage, no

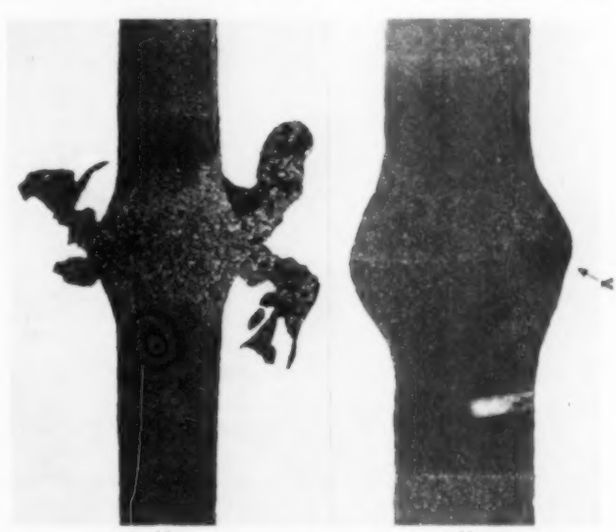


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Fig. 10—Photomacrograph of Resistance Flash Weld in 0.115-Inch Thick, 0.06% Carbon, 0.30% Manganese Hot Strip Taken at 5 Diameters to Show Surface Flash, Necessary Upset and Weld Zone. Etchant Was Nitric Acid Solution

Fig. 11—Photomacrograph of Resistance Flash Weld in 0.180-Inch Thick, 0.06% Carbon, 0.30% Manganese Hot Strip Taken at 5 Diameters. Note Slag Inclusion at *A* Due to Insufficient Heat and Insufficent Amount of Upset to Force Slag Out. Surface Etched 15 Minutes in Nitric Solution at Room Temperature. Heat-Affected Zone Is More Sharply Defined Than in Thinner Strip as Indicated by Fig. 8

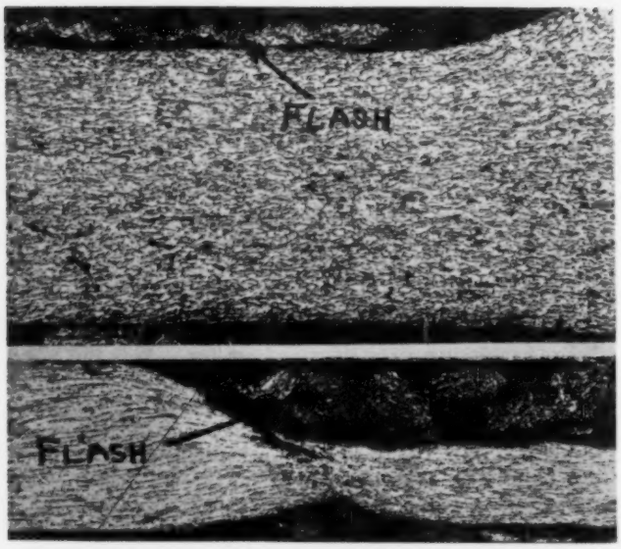

Fig. 12—Flash Welds in Various Stages of Reduction by Cold Rolling Showing Detrimental Effect Due to "Pinching-Off" of Ductile Strip by Remnant of Hard Flash Left on Surface by Improper Trimming

A (Top)—Weld after one pass
B (Bottom)—Weld after three passes

flash or upset removed. In all cases fracture occurred in parent metal at a point well removed from the weld. Such tensile test results are shown in Table 3.

OLSEN TESTS

Using an Olsen tester is a relatively simple method of comparing weld metal with strip metal. Again, as when making hardness tests, the welds must be properly prepared for the test to be of merit. This time it is the type of surface which affects results. If a weld is cut out of the strip and tested "as-trimmed" the Olsen reading will be much lower than a reading taken in the strip away from the weld. This is due to surface markings caused by the trimmer knives. As an example of the effect of these scratches, 0.24% carbon strip gave readings of 510 Olsen, medium, in the parent metal, 408 Olsen, medium, in trimmed weld and 410 Olsen, medium, in trimmed strip with no weld. The strip with trimmed weld and strip with no weld but trimmed were almost identical. To properly make Olsen tests, both strip and weld surfaces should have like preparation. Strip steel of the composition under discussion when tested with a $^7/_8$-inch diameter ball and $1^1/_2$-inch die in an Olsen tester will run 55 to 65 points higher than the weld. A strip reading of 610 and a weld reading of 552 are typical test results.

It is this effect of surface finish for both Olsen tests and cold rolling which make it preferable to trim the weld so hot that a smooth finish is obtained. Proper speed of transfer from welder to trimmer and automatic trimmer operation will accomplish this.

ELECTRICAL REQUIREMENTS

The previous discussion of flashing rates would not be complete without bringing the electrical characteristics of the welder into the picture. For years flash welders have been made with a variable secondary voltage. This is usually accomplished by having either a tapped primary winding in the welding transformer operating off a fixed line voltage or furnishing a variable primary voltage to the welding transformer by means of a tapped auto-coil operating on the fixed voltage line. The secondary voltage could thus be varied in relatively small steps from about 6 to 10 volts. By selecting a proper flashing speed and secondary voltage a schedule was set up for the job at hand. Fortunately for all concerned, low-carbon steel for ordinary welding applications is almost foolproof. It has an extremely wide plastic range, that is, it will bond under pressure over a wide range of temperatures. Empirically it became known that too low a voltage would not flash properly and too high voltage "blew holes in the metal." The general run of most satisfactory voltage seemed to be about 8 volts R. M. S. This is the sustained voltage while flashing. The development of the optimum technique for flash welding of steel strip verified this voltage. Due consideration points out that this flashing potential is almost identical with the dissociation potential of nitrogen as given by Dr. C. G. Suits of the General Electric Company in his October 1935 "Study of Arc Temperatures by an Optical Method." Quoting from this article, "The high degree of dissociation in welding arcs in air, however, means that these arcs are properly regarded as atomic oxygen-nitrogen arcs. . . . V_n = 11.7 volts (8.27 R. M. S.)." V_n is the dissociation potential of nitrogen. Nitrogen makes up 78% by volume of the atmosphere.

Our tests further indicated that once this optimum flashing potential was obtained, it should not be varied as had been done previously but the welding current should be varied by means of welder reactance and flashing speed. A typical flash welder has a low impedance copper circuit and the flashing arc itself is a very large portion of the total welder impedance. This means that the welder is self-regulating as to current demand over a wide range of welded cross sections and flashing rates.

A typical steel-mill flash welder capable of welding a maximum section of $^3/_{16}$ x 40 inches has an impedance such that if the dies were short circuited by a $^1/_2$ x 38-inch copper bar and line voltage sustained, the secondary would deliver 82,500 amperes. If it is short circuited by a piece of solid steel 0.125 x 38 inches, it will deliver

Table 3—Tensile Tests of Resistance Flash Welds of Low-Carbon Steel Strip

Thickness, Inches	Strip Width, Inches	Area, Sq. In.	Yield Point, Pounds Sq. In.	Tensile Strength, Pounds Sq. In.	Elongation, % in 1.75 In.	Distance from Fracture to Center of Weld, In.	Condition of Weld Surface
0.0539	1.002	0.05403	40,240	53,360	15.2*	1.100	Flash and upset removed
0.0543	1.001	0.05437	41,050	53,470	15.8*	1.075	Flash and upset not removed
0.117	1.002	0.1173	37,820	48,650	16.3*	1.450	Flash and upset removed
0.117	0.999	0.1169	36,950	48,540	17.7*	1.500	Flash and upset not removed
0.1805	1.001	0.1809	38,910	64,250	13.2*	1.275	Flash and upset removed
0.1805	1.001	0.1809	39,030	63,690	13.8*	1.375	Flash and upset not removed

All elongations were measured across the weld. Each of the above figures represents the average test values of five specimens. Maximum and minimum values are consistently close to the average values.

* Twenty-nine of the thirty tested specimens broke outside the elongation marks.

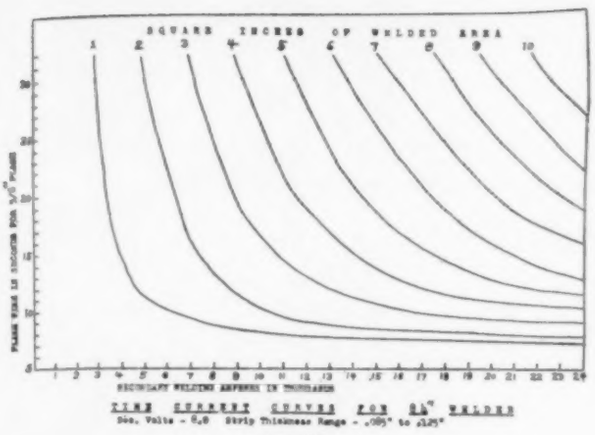

Fig. 13

49,000 amperes. But the same 0.125 x 38-inch plate may be satisfactorily welded at 15,000 amperes while flashing. The impedance of the arc predominates while flashing. Since we have a fixed secondary voltage, as the arc is lengthened by slowing down the flash rate, the secondary current is reduced and vice versa.

Figure 13 shows a set of time-current curves for a welder capable of welding strip 84 x 0.125 inch. The square inches of welded section pertain to gages 0.080 to 0.125 inch. These curves indicate the self-regulation of current with speed and section for a given 8.0-volt secondary and welder impedance. All flash welders have these typical characteristic time-current curve shapes, but the numerical values per curve vary with the welder impedance. If all other variables are held constant and the secondary voltage raised, within limits, all the time-current curves will be displaced to the left, that is, toward a value of less current.

This is not particularly surprising if it is considered in the light of knowledge of metallic arc welding. If the voltage of a metallic arc is raised without speeding up the feeding of the electrode, the welding current is reduced and the arc exhibits the inverse resistance characteristic of electric arcs.

High-speed motion pictures have shown a resistance flash weld to be a very rapidly recurring series of short circuits through small contact points which are heated and expelled as molten droplets. This is accompanied by periods of a gaseous arc sustained by the high temperatures created by the short circuits and protected by gases evolved as products of combustion of steel in air.

The above does not intend to infer that welds cannot be made at voltages less than eight volts. Welds have been made in certain restricted cases using less than one volt. However, again it is indicated that we have found approximately 8.0 volts to be preferred for the scope of welding covered by this article. It should be stated that in line with the slower flashing rates discussed under weld hardness, the optimum current for proper flashing at these speeds is about 3000 secondary amperes per square inch. Such a current is measured with a recording ammeter, and taken as the average of the flashing current.

Figure 14 shows a typical recording ammeter ampere curve made during a weld. The kva. curve is practically a duplicate of the ampere curve as line voltage is essentially constant. The small peak at the start of the flashing current is due to the short circuiting of the strip edges to start the flashing. The small gradual decrease of the flashing current is due to the strip projecting from the dies getting hotter and increasing in resistance. The final surge is due to the loss of flashing arc impedance as the molten strip edges are forged together.

At times it is deemed necessary to weld a very small cross section of steel in a large welder which has so massive a moving member that the high speed to match the available current cannot be reached. In such an instance it is necessary to insert reactance into the welder circuit, to limit the current to a proper value corresponding to a flashing speed available on the welder. All this time the secondary voltage is held in the optimum 8.0 volts range.

As may be readily deduced from Fig. 13, the kva. demand during flashing for a flash weld is rather low. Multiplying any selected secondary amperage reading by the 8.0 volts gives a sufficiently accurate kva. demand reading during the flashing. For a few cycles as shown by Fig. 14, the demand during upset will be higher than the flashing value.

While the power factor of the welder if the secondary were short circuited would be 30%, the power factor while flashing may be of the order of 70 to 80% depending on the section welded and flashing rate.

The kva. rating given a flash welder is quite often very misleading as to its actual load. The kva. rating is a thermal rating and indicates that the circuit will carry the rated kva. load at a 50% duty cycle without exceeding a given temperature rise (55 or 80° C. as the case may be). The actual welding load in most strip welders is not even one-tenth the rating. The duty cycle, being very low due to other factors, is the greatest single reason.

Another reason for such a discrepancy of rating and loading is the fact that designing a circuit of sufficiently low impedance automatically obtains a high thermal rating. For most large strip welders a rating of 1000 kva. is no better in performance than a 250-kva. welder-provided the 250-kva. welder has a sufficiently low impedance to weld the maximum section the welder is capable of clamping and upsetting. It is this high thermal rating which is the reason for the disuse of transformer cooling water in a number of large installations.

SUMMARY

The resistance flash welding of steel strip has a definite place in steel mills and is capable of producing highest quality welds at a high production rate with low maintenance and using relatively unskilled labor.

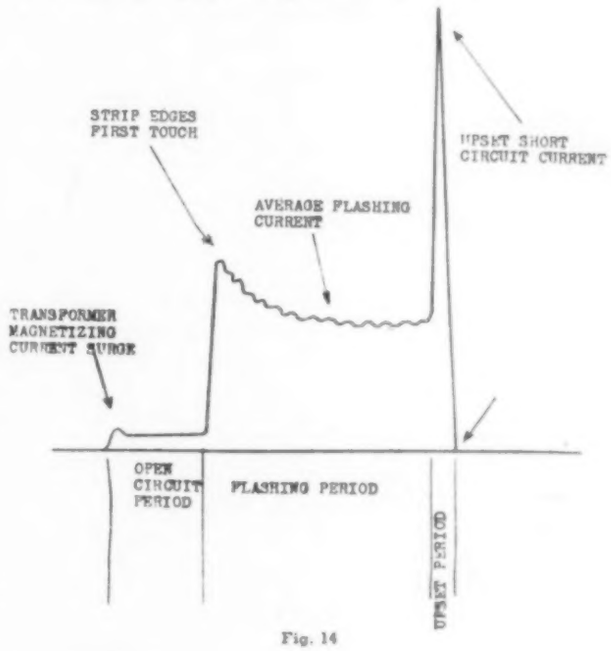

Fig. 14

TRAINING OF WELDING OPERATORS*

By S. LEWIS LAND†

IT WAS my privilege to appear on the program of one of your conventions held in New York City in 1932. At that time training programs for welding operators were in their infancy. In the meantime, rapid progress has been made in the improvement of equipment, in the development of new processes and in the introduction of welding into new fields. Rapid progress has likewise been made in the number and kind of training programs established to meet the needs in the various fields served by the welding industry.

In the development of programs for the training of operators for welding, consideration must be given to (1) the adequacy of relationships to be established between industry and school agencies, (2) wise selection of those to be trained, (3) modern equipment for school shops and classrooms, (4) organization of a course of study adequate to meet the needs of the field to be served, (5) accurate and reliable instructional material, (6) properly qualified instructors, (7) checking results of instruction and (8) provision for placement of graduates.

Whether the training program is of the trade preparatory type, training boys on an all-day trade preparatory basis for later entrance upon employment in some specialized field, or of the trade extension type, training boys and older men on an evening trade extension basis for greater efficiency in the work at which they are already employed, high standards in these eight divisions are important and are essential to the success of the program.

Likewise, whether the program is one organized as a part of the public schools or a private trade school, the same basic standards should be maintained.

RELATIONSHIP BETWEEN SCHOOL AND INDUSTRY

In the organization and maintenance of programs for the training of welding operators, desired results can be achieved only when there is established and maintained the right kind of relationship between school agencies, employers and labor. In the State of New York, the State Education Law makes mandatory advisory boards for vocational education in all cities and school districts maintaining vocational training programs. Such local advisory boards are charged with the responsibility of making studies and surveys for the purpose of determining needs for specific types of vocational training, establishing subcommittees to assist in the work of preparing studies and reports for the board of education regarding vocational training needs and promoting generally the establishment of vocational training programs in the community.

In small towns and cities, one advisory board representative of industry and labor may meet the need for all industries. In larger cities, subadvisory boards representing each of the major industries are appointed to work under the general direction of the advisory board provided for in the State Education Law. The importance of maintaining close working relationships between school agencies and industry through such advisory boards cannot be stressed too strongly. The maintenance or lack of maintenance of such coordination may mean the difference between complete success and total failure in programs for the training of welding operators.

SELECTION OF TRAINEES

Choosing a beginner who is to be enrolled in a welding training program is as important as his training. If care is taken in the selection of persons to be trained, the development of first class welders is assured. From the point of view of the employer who is employing a man who will be enrolled in a trade extension type of training program, thirty minutes' time spent in the study of the man's qualifications will prove to be more valuable and less expensive than an insurance policy insuring his success. Careful selection of those to be trained will also eliminate those who are likely to be poor material because of either physical or mental disabilities. The employer who fails to investigate the physical and mental capacities of his employees will find this policy an expensive one in the employment of welding operators because the initial training period is an expensive one, and incompetent men are frequently carried on the payroll for some period of time before their deficiencies are discovered.

In addition to an examination for applicants for training, those who apply for employment making claims of welding competency should be tested in line with the standardized qualification procedure adopted by the AMERICAN WELDING SOCIETY. The development of adequate procedures for the selection of persons to be enrolled in both day trade preparatory courses and trade extension training programs should be a cooperative undertaking on the part of the school with the advisory board from industry.

COURSE OF STUDY

It is obviously impossible to suggest in this brief presentation a course of study which would meet the needs in all fields served by the welding industry. Contrary to the belief of some, welding may not be considered as a separate and distinct industry. The welding process cuts across a large number of industries: Aviation, railway, ship construction, sheet metal, piping, automobile, structural steel and others. In the interpretation of the American Federation of Labor, at least, a welder as a separate mechanic does not exist. The American Federation of Labor declared in its 1916 convention that welding is a process and that the welder's torch is a tool to be used by each separate mechanic in his particular field. Specifically the convention declared

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, October 21 to 25, 1940.

† Supervisor of Industrial Education, The State Education Department, Buffalo, N. Y.

that "We recommend that this convention declare that acetylene welding is a process and that an acetylene welder is a tool which can no more come under the exclusive jurisdiction of any one trade or calling than can the hammer or the saw."

The same decision was reaffirmed by the 1919 convention of the American Federation of Labor. In a decision rendered April 28, 1920, in the matter of a dispute between tradesmen in various trades concerning the jurisdiction of welding, the following agreement was concurred on: "Representatives of the electrical workers, sheet metal workers, iron workers, plumbers, steam fitters and machinists mutually agreed to the following decision, each trade to have jurisdiction over all acetylene and electric welding when such process is used to perform the work of their respective trades."

Notwithstanding this declaration of policy, courses of study in general welding may be justifiable in large industrial areas where job welding shops or large manufacturing plants employ welding mechanics in adequate numbers to justify the establishment of such classes. In these cases the demand frequently is for combination electric and gas welders. Wherever the numbers to be trained justify it, however, separate classes should be established and separate courses of study provided for adequate training in both the electric and gas processes in the several fields—welding for sheet metal workers, welding for auto mechanics, welding for steam fitters, welding for aircraft workers, welding for structural steel workers, welding for factory maintenance men and the like.

Full time day courses of study should provide for instruction in shop practice and related technology and in non-vocational subjects. On the basis of a six-hour school day, 30-hour week, 15 hours should be devoted to shop practice and shop theory, $7\frac{1}{2}$ hours to related technology—including instruction in applied mathematics, applied science and applied drawing, and $7\frac{1}{2}$ hours to non-vocational subjects—including instruction in English, Civics and Industrial History.

For the evening trade extension type of training program, the most effective course of study can be organized on the basis of short units. Here the purpose is that of giving instruction supplementary to the daily employment of persons over 16 years of age who have already entered upon employment.

INSTRUCTIONAL MATERIAL

Drastic changes which have been made in new and improved tools and equipment, new processes which have been and are being developed and the trend toward standardization in procedure make necessary the constant revision of instructional material used in training programs. The instructor who fulfills his responsibility in this regard must be able to revise and write his own job instruction sheets. Much material, however, is available which can be used as basic reference material. The manufacturers of welding equipment and supplies have provided materials and engineering assistance which can be used to advantage. Some of the trade associations representing industries where the welding process has recently been introduced have developed materials which can be used to very good advantage in their specialized fields. Typical is the "Standard Manual on Pipe Welding" developed and published by the National Association of Heating and Air Conditioning Contractors.

Instructional material must be of two kinds: (1) Job instruction sheets and (2) related instructional material. Job instruction sheets contain, step by step, procedures in the doing of particular jobs, the listing of the apparatus, tools and materials used in the job, together with safety precautions and other suggestions for the instructor and student. Related instructional material provides material and data on welding construction including the designing, laying out and fabrication of various types of welded joints, engineering and practical data, and specifications and standards covering the welding procedures to be followed in the particular field.

Because carelessness or lack of ability in the proper operation of welding equipment may result in excessive costs and even in hazards to both life and property, it is extremely important that rules and regulations having to do with precautions and safe practices be incorporated as a vital part of the instructional material. The National Board of Fire Underwriters has adopted rules and regulations which may be obtained from them. Insurance companies publish materials which can also be used to advantage. The manufacturers of equipment likewise publish precautions and safe practices to be followed in the operation of their equipment which should also become a part of the instructional material.

EQUIPPING THE WELDING SCHOOL

Quarters to be assigned to a welding school depend, of course, on the space which may be available. A shop 30 x 50 feet with a floor area of 1500 square feet will prove satisfactory for a welding work room to accommodate a maximum of eighteen student welders, a small lecture room and library, wash room, a small store room and space for other materials and equipment needed in a welding training program. A lecture room is not essential since the welding work room may be used also for lectures and class instruction, or a related subjects room may be available for use in another part of the school building. When it is desirable to assemble the class for shop talks, the space between the welding tables can be filled with folding chairs and the chairs removed after each lecture period.

Experience has shown that effective instruction can be given to a group of not more than eighteen students by one instructor. If instruction is to be given to larger numbers, the groups should be separated into two or more sections.

The welding work room should provide ample space for twelve to sixteen welders, twelve to sixteen welding tables, a scrap box, a quenching tank and a table with vice for bend testing.

A lecture and assembly room should preferably be provided for assemblies, lectures, individual lockers, instructor's table, blackboard and demonstration apparatus.

A small store room or steel cabinets should be provided for equipment not in use, goggles, fluxes and the like. Adequate fire extinguishing equipment should be provided and kept in good working condition at all times. Individual lockers for each student provide for the safety of his street clothes and valuables during school hours. Wash room and toilet facilities should, of course, be available for the class.

For acetylene welding, tables 4 to $4\frac{1}{2}$ feet in length, 24 to 36 inches in width and 30 inches high should be arranged in U formation or a hollow square in the center of the room to facilitate the instructor's observation. Tables with sheet steel tops may be used. Another type of table is that made of steel angles or welded pipe with a welded grid for the top on which are laid fire bricks to form a working surface. Each welding table should be

provided with one set of steel vee blocks, two fire bricks and a sheet iron baffle to protect the adjacent operator and apparatus from sparks when cutting.

For electric welding, the welding stations may be arranged around the outer edge of the shop so that the welding machines are located against the wall and the operator's table is located in the front of them. The welding table should have a shield built around on three sides and should extend upward for a distance of about 30 inches. The open side at which the operator works should face the welding unit to enable the operator to make his adjustments easily. A piece of the type of glass used in welding shields installed in the shield around the welder's table directly in front of the welder will enable the instructor to observe the student at work and will provide a means for the instructor to demonstrate correct and incorrect methods of procedure to the student. Locating the electric welders along the outer walls simplifies the wiring of the electric service lines. The use of attachment plugs and flexible type reinforced cable for connecting to electric service receptacles located on the wall, makes it convenient to move or change the units as conditions require.

A diamond wire mesh tool crib for the housing of wrenches, pliers, tongs, helmets, hammers, punches, clamps, steel rules, squares, tips, cutting heads, drills, snips and other hand tools is a necessary unit. Tools and welding equipment should be located so that they are easily and quickly secured without loss of time and so arranged that missing units are quickly discovered at the close of the session. Mounting the tools on tool boards on the walls and painting the tool on the tool board will reveal a missing tool at once.

A super structure made of angle iron or similar material about eight or nine feet high will provide facilities for pipe welding with working conditions similar to those found in industry and will provide practice for the making of pipe welds while working from a ladder or scaffold.

Only the latest and most up-to-date equipment should be used in the training of welding operators. Obsolete and worn out equipment make for ineffective training and provide additional hazards in the school shop.

INSTRUCTORS

It goes without saying that the key to the success of the training program is a qualified instructor. A thoroughly capable instructor may make a success of a training program in spite of deficiencies in equipment, instructional material and other factors usually considered essential to a successful training program. A poor instructor, on the other hand, even when provided with the best in equipment, course of study and instructional material will produce mediocre results in a training program.

Instructors are of two kinds: those who teach the practical shop work and those who teach the related technology—related mathematics, related science and related drawing. These two types of instructors must possess different sets of training, experience and other qualifications. The instructor who teaches the practical shop work must, first of all, be a thoroughly qualified welder, and then he must be a good instructor. The instructor who teaches the related technology must, first of all, be a good engineer, and then he must be a good instructor.

The requirements for provisional certification for these two types of instructors in New York State, which are typical of the requirements in other states, provide that the shop instructor must have completed a minimum of nine years' appropriate practical experience and 32 semester hours, or the equivalent of one year's college work in professional courses, and that the related technical instructor must have completed a four-year degree program in an engineering college, a minimum of three years' appropriate practical experience and at least 6 semester hours in professional courses.

CHECKING RESULTS OF INSTRUCTION

The knowledge, skill and judgment of pupils should be tested and found satisfactory at regular intervals before new work in the course of study can be undertaken. Testing serves three purposes. It determines the progress made by the individual, it acts as a review of the work covered in past instruction and it shows the instructor where his instruction has been weak in subject matter or in method or both.

Testing for knowledge and skill involves two distinct operations. Separate tests must be given for each. This is necessary because the student may be well advanced in general knowledge of the welding process and yet have no skill, or he may be skillful in the operation of the welding torch and yet be lacking in related information. Although tests for knowledge and skill require separate examinations, the content of each may be related to the other. A performance test may be given which involves the application of principles of the theoretical and technical phases of the welding process. Performance tests administered at intervals during the course of training should cover the important skilled operations which have been taught. Tests for knowledge can be made orally or written, while tests for skill must be made through the performance of specific operations selected for examination.

The results of these tests administered at periodical intervals during the course of training furnish a complete history of the student through his entire training period. These records constitute an improvement record or a record of progress and should be recorded from the time the student is first tested until he has completed his entire period of training. Accurate recording enables the instructor, the student and the prospective employer to know at any time the exact amount of progress which any student has made.

PROVISION FOR PLACEMENT OF GRADUATES

In the case of evening trade extension programs, students in training already have jobs. The responsibility of the school and instructor to these students is that of aiding the student, in cooperation with the employer, in his program of advancement. In the case of all-day trade preparatory training programs, the school and instructor have a definite responsibility to the student for assistance in his satisfactory placement at the conclusion of his training program. The record of placement of the school is proof of the degree of effectiveness of the training program. If the right kind of relationship has been established and maintained between school and industry and if high standards have been maintained in connection with each of the other items mentioned here, the placement of graduates should follow as a matter of course. In fact, if the school maintains the right kind of training program, it will become a source of employment to which all prospective employers will turn when in need of the services of an intelligent apprentice for the trade.

COST AND PROCEDURE CONTROL by Use of Polarized Light*

By E. W. P. SMITH†

WELDING, the most basic cost reducing process known, must be properly and adequately applied and used, if the maximum results are to be obtained. Such an obvious statement is often admitted but observance in actual manufacture is frequently more or less casual, due to lack of appreciation of the full import of the statement.

Cost.—The control of cost involves many and varied factors, when by cost is meant the cost per unit of performance.

The cost per unit of performance is equal to money units (dollars and cents) divided by performance units. Obviously cost may be reduced by decrease of the money item or increase of the performance item, or both. A startling and very common illustration of reduction of the money item is the simple butt joint with excessive reinforcement (see fig. 1).

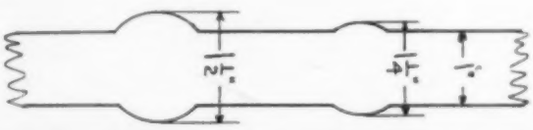

Fig. 1—Butt Joints—25% and 50% Total Reinforcement. Sound Procedure Control Will Reduce Cost of Joint by Using Less Metal, by Better Use of Metal, Better Stress Distribution

As will be shown later, the reinforcement is not particularly useful as a carrier of stress. The reinforcements for a double "U" joint in a 1-inch plate 25% total, 12½% on a side weighs 0.391 lb. per ft. and for 50% total, 25% on a side 1.1 lb. per ft. At $1.00 per pound for deposited metal (see "Procedure Handbook," Sixth Edition, p. 215), this is an additional or excess cost of $0.39 and $1.10 per foot, respectively, which may be reduced materially without affecting performance. Figure 2 (*a*) shows this graphically.

Another illustration is the fillet bead. If this is unduly reinforced the cost per foot is greatly increased and, as will be shown later, with no particular increase of performance, in fact, quite frequently the reverse is true. If, for example, an average 45° fillet is compared to one with very full or over reinforcement the increased cost per foot will be of the order of 30% or more. This is shown in Fig. 2 (*b*).

Further study of other types of joints, some of which are shown later, leads to the same relative cost reduction. The additional metal is of no great use from a stress or load carrying view-point and it costs money to place it in position, which leads to the matter of stress distribution and the use of material for load carrying purposes.

This consideration of use of material, in so far as stress distribution is concerned must be from the general viewpoint of uniformity of stress distribution and not for just one special case, such as limiting the maximum

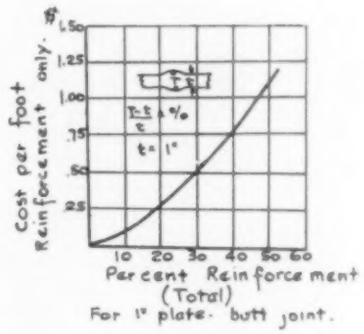

Fig. 2(*a*)

stress to the commercial endurance limit regardless of stress values at points other than at a particular, very highly stressed point.

The economy is obvious. For example, the endurance limit of good weld metal, deposited by the shielded arc is of the order of 32,000 lb. per sq. in., as is also that of steel. If in any part of the joint, the unit stress does not exceed this value, the joint will perform properly or at least adequately. However, there may be, and usually is, some general stress limitation. If this limit is any lower than the above figure than either the 32,000 lb. per sq. in. is too high and should not be permitted in any part of the structure, or, the other stress is too low. A logical or balanced design would require the use of the metal throughout to the stress limits, and consequently would result in a cost reduction. There may be cases, and there are, where this desired objective of uniformity of stress is difficult of attainment. But that should not prevent a study so that the result will be as near this low cost objective as possible. The peak or top stress is the governing factor in determining load capacity. If the stress may be more uniformly distributed, more load may be carried and a reduction of cost of unit performance obtained, or for the same load a smaller section may be used resulting in lower money item. The problem should be solved by uniformity of stress distribution,

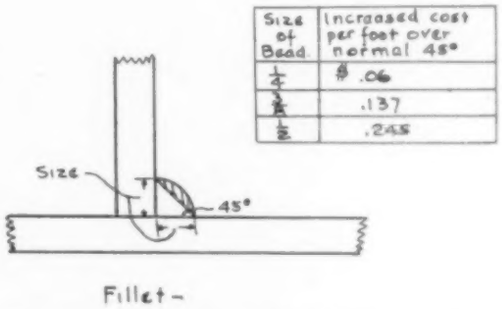

Fig. 2(*b*)—Heavily Reinforced Fillet Compared to Normal 45° Fillet

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Consulting Engineer, The Lincoln Electric Company, Cleveland, Ohio.

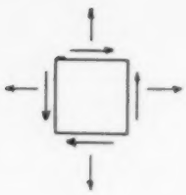

Fig. 3

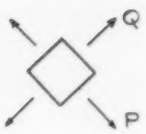

Fig. 4

whether stresses be high or low, and the result is a cost reduction.

Cost reduction by this method is most easily and effectively accomplished by use of welded joints, because of their inherent superior stress distribution. Much has been said and written about stress distribution in welded joints and it might be inferred that only welded joints must be studied. The study of welded joints is to take full and complete advantage of their excellent characteristics. A rather casual examination of some other type of connection brings this superiority out most emphatically, e.g., a single riveted joint as shown in Fig. 27.

To study stress distribution a number of methods are available, among them the use of suitable models and polarized light. The method is simple, effective, easily applied and reasonable as to cost. Where the problem or design of joint may be considered in two dimensions, the solution may be obtained relatively quickly, and easily and with an accuracy in line with the refinements of the design or part, by means of stress analysis based on a study of a stressed model of suitable material placed in a beam of polarized light and the resultant effects on the polarized beam. Direct study of a single model may be made, or two joints may be placed on the same model and a comparison made. That joint which shows high stress first, is the first to be rejected. The model retained is modified, then compared to a third model and the process repeated until a satisfactory low cost answer results.

An outline of this method involves a consideration and discussion of a few principles of stresses, of the theory of light and a simple explanation of the equipment and methods involved.

If from a plane of a part subjected to loads a small element is removed there will exist along the sides of this element forces as shown in Fig. 3. Along each side is tension, or compression and also a shearing force.

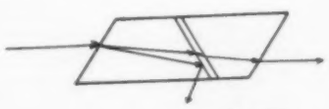

Fig. 5

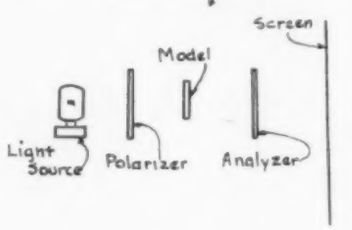

Fig. 6

It is possible so to select the elements that only tension or compression occurs on each side. These stresses are known as the principal stresses, P and Q, Fig. 4. This condition exists for only one direction at each point, and in general is different for all points. The maximum shearing stress at any one point is $(P - Q)/2$ or half the difference of the principal stresses.

Use is made of the fact that the shear is equal to half the difference of the principal stresses in explaining the method of polarized light. Common or ordinary light

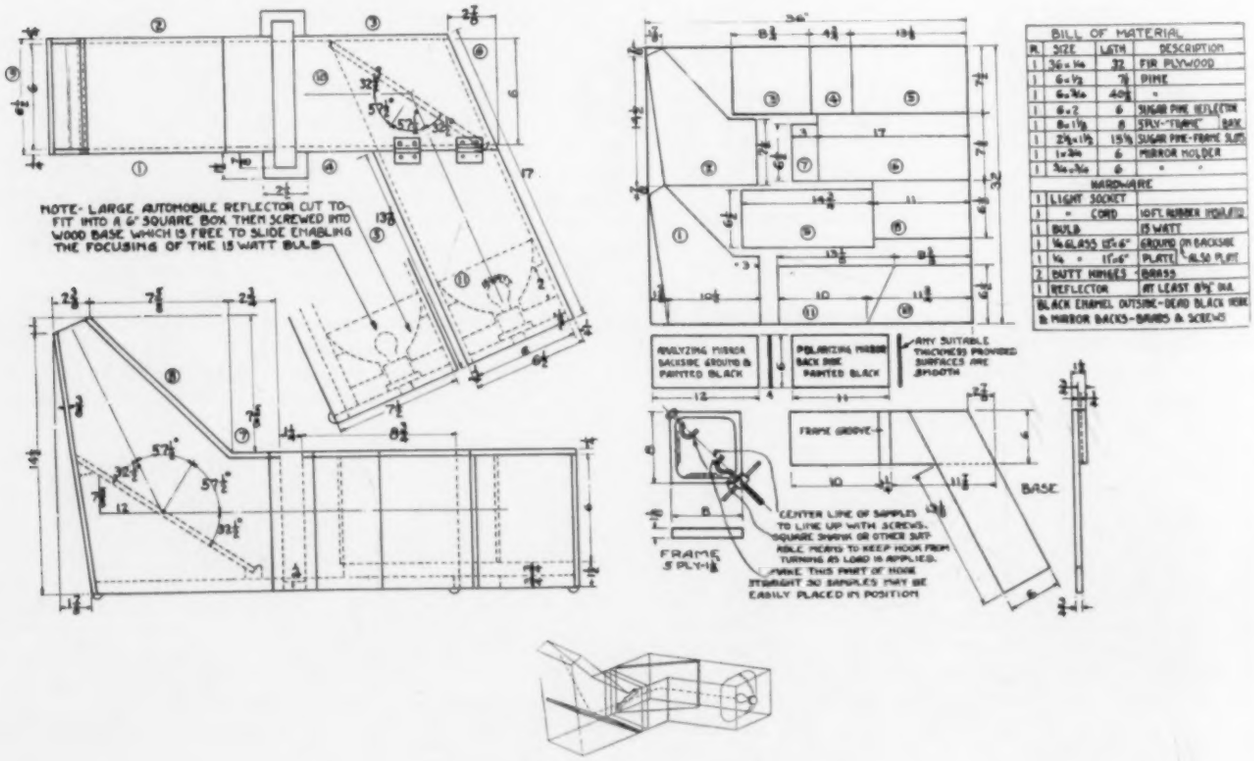
NOTE- LARGE AUTOMOBILE REFLECTOR CUT TO FIT INTO A 6" SQUARE BOX THEN SCREWED INTO WOOD BASE WHICH IS FREE TO SLIDE ENABLING THE FOCUSING OF THE 15 WATT BULB
BILL OF MATERIAL
R. SIZE LGTH DESCRIPTION
1 36 x 1/4 32 FIR PLYWOOD
1 6 x 1/2 7/8 PINE
1 6 x 3/16 40 3/4 "
1 6 x 2 6 SUGAR PINE REFLECTOR
1 8 x 1 3/8 8 STAY-"FRAME" BACK
1 2 3/4 x 1 3/8 15 1/8 SUGAR PINE-FRAME SUPP.
1 1 x 3/4 6 MIRROR HOLDER
1 5/16 x 3/16 6 " "
HARDWARE
1 LIGHT SOCKET
1 " CORD 10FT. RUBBER INSULATED
1 BULB 15 WATT
1 1/16 GLASS 12" x 6" GROUND ON BACKSIDE
1 1/16 " 11" x 6" PLATE ALSO PLATE
2 BUTT HINGES BRASS
1 REFLECTOR AT LEAST 8 1/2" DIA.
BLACK ENAMEL OUTSIDE-DEAD BLACK INSIDE & MIRROR BACKS-BRADS & SCREWS
ANALYZING MIRROR BACKSIDE GROUND & PAINTED BLACK
POLARIZING MIRROR BACK SIDE PAINTED BLACK
ANY SUITABLE THICKNESS PROVIDED SURFACES ARE SMOOTH
FRAME GROOVE
BASE
CENTER LINE OF SAMPLES TO LINE UP WITH SCREWS. SQUARE SHANK OR OTHER SUITABLE MEANS TO KEEP HOOK FROM TURNING AS LOAD IS APPLIED. MAKE THIS PART OF HOOK STRAIGHT SO SAMPLES MAY BE EASILY PLACED IN POSITION
FRAME 5 PLY

Fig. 7—Reflecting Type of Polariscope

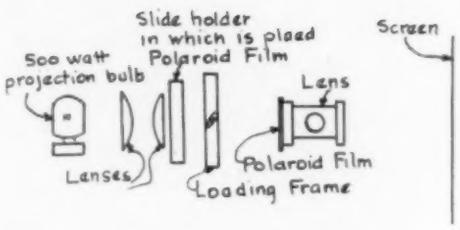

Fig. 8—Slide Projector Polariscope

may be thought of as a series of transverse vibrations of ether particles similar to the motion of the particles of a stretched wire when it is struck perpendicular to its length. This vibrates in one plane only whereas light or ether particles vibrate in all planes containing the line which the light ray follows. If the ether particles of the light ray can be made to vibrate in a single plane, just as the particles of the wire do, then a ray so vibrating is called "plane polarized."

Another example visualizing or illustrating the difference between common light and polarized light is that of a pond, the surface of which is smooth. If into this pond a handful of pebbles is thrown, the resulting waves going in all directions may be thought of as common or ordinary light. If, however, by some suitable mechanism only one pebble is permitted to drop into the pond, the resulting wave may be thought of as polarized light, and the surface of the pond as the plane of polarization.

Similar to the "suitable mechanism" mentioned above, certain optical systems have the peculiar property of breaking a common ray into polarized light. Only in this case there are two rays at right angles to each other and not one. These two rays are "plane polarized." By suitable means one of these rays may be absorbed and the other comes through as a single ray.

When a common beam of light, indicated at the left of Fig. 5, strikes a suitable crystal it is broken into two rays each plane polarized and vibrating at right angles to each other, one for example, in a vertical plane and the other in a horizontal plane. The ray vibrating in the vertical plane travels faster and is deflected through a smaller angle than the ray vibrating in the horizontal plane. If the cut between the crystals is made at the proper angle the plane polarized ray vibrating in vertical plane will pass through the crystal and be deflected back parallel to its original direction. The other ray will be reflected to the side, and absorbed, if the side of the equipment is suitably blackened.

Thus, a common beam of light with vibrations in all directions is first broken into two rays vibrating in two directions, one of these rays is absorbed and the other emerges vibrating in one direction only, "plane polarized."

Light may also be plane polarized by reflection, by transmission through a series of glass plates, and there

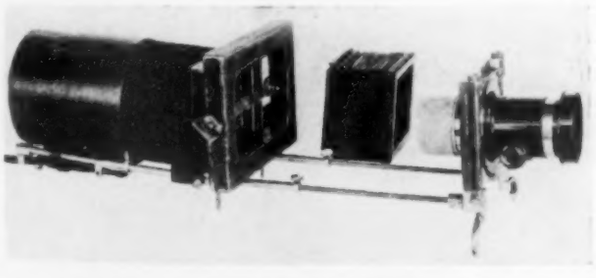

Fig. 9—Slide Projector Modified to Project Models on Screen

are on the market suitable polarizing devices, some of relatively low cost.

If two prisms or polarizers are set so the ray of light emerging from one passes through the second, they are "parallel." If, however, the second is then rotated 90°, they are "crossed" and the ray of light from the first will enter the second, but be reflected or absorbed so light will not pass through the second prism.

Materials such as glass, celluloid and bakelite, which normally have equal properties in all directions, when stressed, act exactly as does this crystal mechanism.

Fig. 10—Effect of Abnormal Reinforcement

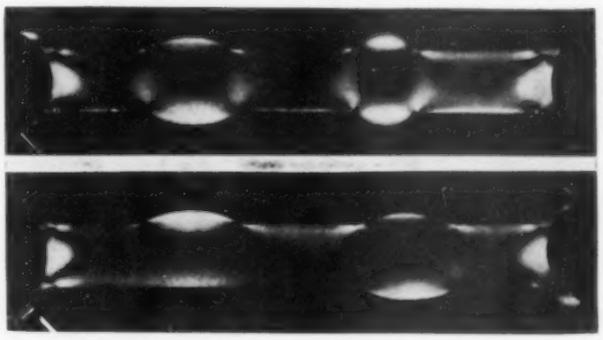

Fig. 11—Comparison of Single and Double Reinforcement

They break any beam of light into two rays which are plane polarized. These two rays possess interesting and useful characteristics. They vibrate parallel to the principal stresses, P and Q, and are proportional to them, consequently, their difference is proportional to the shear, $(P - Q)/2$. One ray travels faster than the other and if the beam strikes the material being loaded perpendicular to its surface, so neither ray is deflected through any angle, one ray will emerge ahead of the other. The resultant effect may be illustrated by considering two conditions. If, as the rays leave the material, one ray is *any* number of *full* wave lengths ahead of the other, the two will combine or result in a beam exactly the same as the original or impinging ray. If one ray leads the other by any *odd* number of *half* wave lengths the beam resulting will vibrate at right angles to the original or impinging ray. The amount one ray will emerge ahead

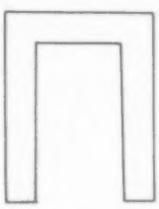

Fig. 12

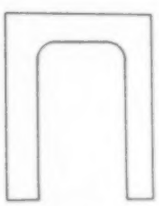

Fig. 13

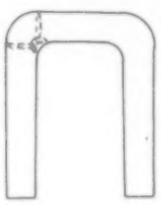

Fig. 14

of the other depends upon the difference between the principal stress $(P - Q)$ and is therefore proportional to the shear.

To illustrate these conditions a rather simple equipment is used. A schematic or outline of set-up is shown in Fig. 6.

From the light source light passes through the polarizer and emerges as plane polarized light, vibrating for example vertically. Assume the model is not in position, then the light (vertical) enters the analyzer, which is set 90° to the polarizer so no light reaches the screen. If a stressed model is placed between polarizer and analyzer,

Fig. 15

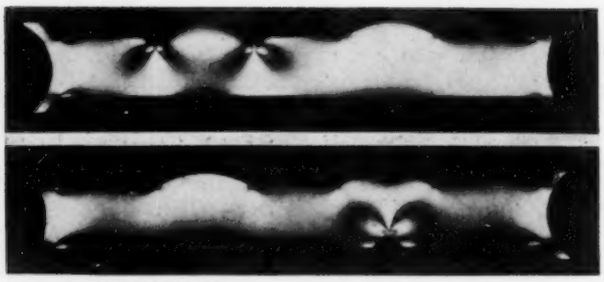

Fig. 16

a light ray from the polarizer strikes the model, at a certain point, is broken into two rays and they recombine as they emerge. If at the particular point under discussion the difference in the principal stresses results in the rays being one half wave apart, a horizontal ray results. This passes through the analyzer and a light spot is shown on the screen. At another point the two rays may emerge one wave length apart. Their combination as they emerge from the model results in a vertical vibration, and no light passes to the screen. There will be on the screen for a given model a series of light and dark bands characteristic of the type of loading. This will show the locations on the model where the difference in the principal stresses $(P - Q)$ is such as to cause the rays to emerge one half wave length apart or light spot, two half wave lengths apart or dark spot and so on. There are other points at which other differences, and variations occur other than those mentioned, i.e., one half wave length, two half wave lengths, etc., consequently the light and dark areas or bands, or lines change from one to the other, gradually. The terms light and dark have been used indicating a single-color light source. White light may be used. This is made up of all colors and the bands gradually change in color from one color through all the others and back to the same color, instead of from dark to light and back again.

When white light is used, the image of the model thrown on the screen shows a series of color bands which bands indicate the distribution of the shearing stresses. By considerable number of other observations and calculations the values and paths of the actual stresses may be obtained. This, however, is infrequently required. The points of stress concentration may be located by observation and different designs compared. Stress concentrations occur wherever there is a marked *crowding* together or *abrupt curving* of the bands. Comparisons of different designs are thus readily made by studying patterns of models of these designs and making comparisons. It is usually evident what changes should be made. This is done, a new model prepared and studied, and the process continued until a satisfactory solution is indicated. It will generally be true that when the final design is determined calculations are greatly simplified.

The designer or observer might well think of the distribution of stress as similar to the flow of water. Uniformity of stress to as great a degree as possible, and thus low cost of product, is to be obtained by gradual changes in section, omission of irregularities, external and internal, just as turbulence, splash, is avoided in a flume.

Figs. 19 and 20—Heavy Large Bead Is Very Costly and Does Not Add to Performance

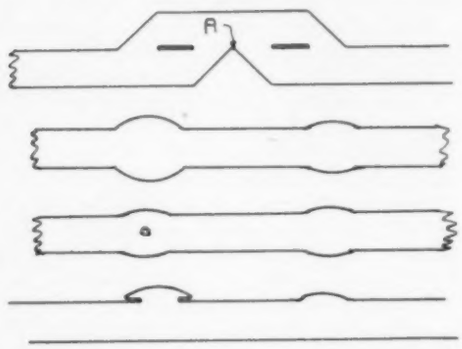

Fig. 21—Good Procedure Will Correct This Lack of Fusion and Very Greatly Improve Performance

Fig. 22—Overlap Is Evidently a Waste of Metal

The mechanism for this study may be a simple reflecting type of polariscope, low in cost such as shown in Fig. 7. Or, for projection purposes a more elaborate setup as shown in Fig. 8 and Fig. 9. These show a slide projector modified to project models on the screen.

This method is quite frequently used in a direct comparative way. For example, two joints are placed on the same specimen so they are both subjected to the same load. As the load is applied, that joint which colors first, either locally or generally, is most highly stressed and is to be rejected.

Cost.—For example, by use of reasonable reinforcement in a butt joint, cost may be reduced. It is advisable that the reinforcement be as small as possible, a uniform section being most desirable, from cost standpoint, but in the commercial attainment of this objective, it may be better to use just a slight reinforcement, as this is easier to obtain than an absolutely flat joint.

Note in Fig. 10, abnormal reinforcements carry very little stress, with result, excess material and high cost. Compare this to the more normal joint adjacent. In the same way, a single reinforcement may be compared to a double reinforced joint, Fig. 11.

Fig. 17

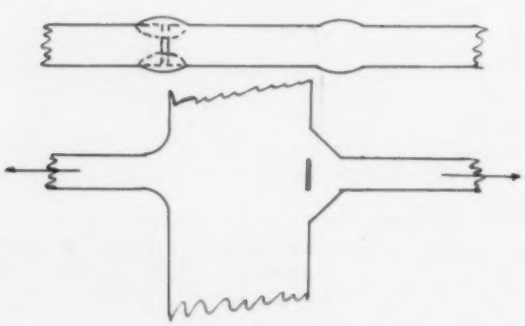

Fig. 18

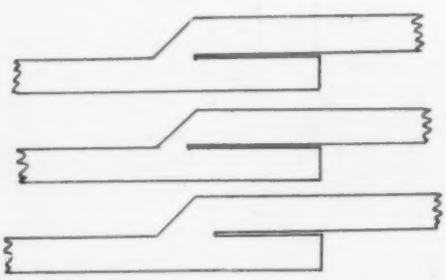

Fig. 23—Comparison, Three Degrees of Penetration in Single Bead Lap Joint. A Lap Joint Is Eccentrically Loaded. The Combination of Bending and Direct Tension Results in High Local Stresses. Because of This, These Joints Must Be Properly Applied and Made

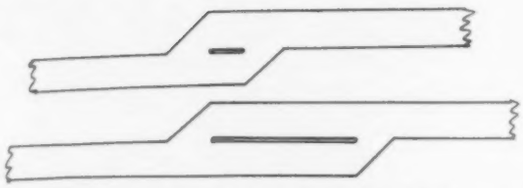

Fig. 24—Comparison Effect of Overlap of Two Bead Lap Joints. The Overlap Should Be Not Less than 4 or 5 Times the Plate Thickness

Even in the double vee joint, which is symmetrical, the stress is not completely uniform as to distribution. Reinforcements are not carrying stress to extent other sections are and, therefore, the metal of the joint is not used to advantage; reduction of reinforcements would reduce costs. Similarly, costs may be reduced in fillet welds by keeping excess metal to a minimum.

An illustration of better uses of metal is a simple frame such as shown in Figs. 12, 13 and 14. Figure 12 is obviously a poor shape. The outside corners have low stress and inside corners high stress. Figure 13 is an improvement on inside corners, and Fig. 14 an improvement of both. Note how, by the selection of the proper electrodes, the corner joints of Fig. 14 may be made to conform to good performance and low cost.

Procedure.—The very evident and substantial cost reductions made possible by proper use and placement of metal lead to consideration of the actual placement that is procedure or workmanship. The procedure and workmanship control another cost factor, that is, performance. Any interference with stress causes a disturbance with resultant impairment of performance. For example, undercutting compared to normal joint, as shown in Fig. 15. The crowding together of lines and quick change of direction show effect of undercutting. Contrast this to result shown on the right. Correct procedure improves the use of metal for better performance of product.

Fig. 25—A Butt Strap Is of No Great Help in Improving Performance, and Under Certain Conditions, Causes Reduction in Performance. It Carries Very Little Stress, Makes an Eccentric Loading of the Joint and Should, in General, Be Avoided

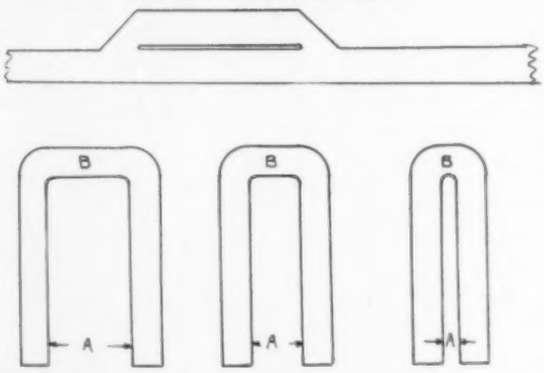

Fig. 26—Showing Effect of Reduction of Throat Dimension (A) on Bending Stresses and Change in Location of Neutral Axis at (B)

Another example of the same general kind is a single vee with lack of fusion at the root, Fig. 16. The crowding together of lines and quick change of direction indicate high stresses and poor use of metal. Properly made, the joint gives normal performance and cost is low per unit of performance.

Lack of fusion at the bottom of the single vee, inexcusable in a good welder, shows failure to fuse the bead completely to the sides and bottom of the vee, and results in a notch effect. Direct tension plus bending result in very high, localized stresses. Good procedure corrects this and results in cost reduction. In the case of square groove butt joint, Fig. 17, the effect of the internal notch effect is obvious, as is the correction and resultant cost reduction by improved performance.

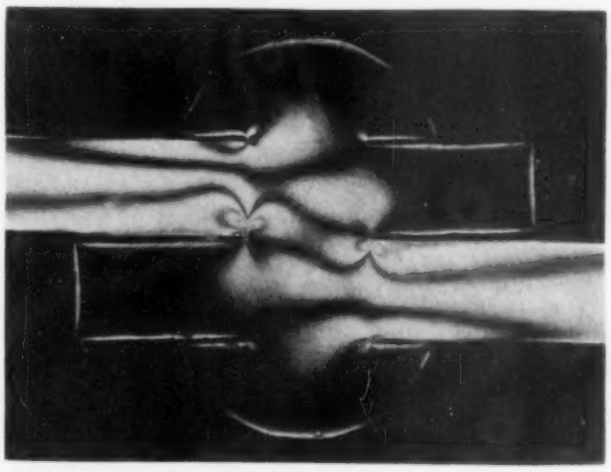

Fig. 27—A Single Rivet Lap Joint. The Quick Change of Direction and the Crowding Together of the Lines at the Intersection of the Rivet and the Base Metal Indicate Very High Stresses at These Points. This Method of Cost and Procedure Control by Use of Polarized Light Permits an Investigation of Stress Conditions Existing in a Joint or Part of Mechanism. A Knowledge of These Conditions Results in a Better and More Effective Use of Material, Weld Metal and, Therefore, Lower Costs. Due to the Ease and Freedom of Fabrication by Welding, Adjustments May Be Made and Every Part Utilized to the Best Possible Advantage, Resulting in Low Weight and Cost

A joint very similar to this is shown in Fig. 18. Here the procedure is correct, but the type of joint is improperly applied, the load being transverse to the bead, resulting in an internal notch effect. Along the same line of proper procedure for bead, but most improper placing of bead is shown in Fig. 19.

This type joint must not be used as the stress at (*A*) when joint is only very *lightly* loaded is *very high* and greatly localized resulting in a high cost in metal used (four beads) and in *very poor* stress distribution.

Numerous other examples might be given but those discussed are sufficient to illustrate the method for particular application to a specific problem. In Figs. 20 to 27 are outlined several suggested comparisons.

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ANNUAL BANQUET

The Annual Banquet is to be held in the Ball Room of the Cleveland Hotel, Cleveland, Ohio on Thursday Evening, October 24th at 7 P. M. Only 400 seats are available. Make your reservations early. Tables going fast. Preference given in order of receipt. Tables and seats numbered. Price $4.00. Bring the ladies. Good time promised.

WELDING IN TANK CAR Construction*

By JOHN W. SHEFFER†

ABOUT 40 years ago, the heavier service demanded of railroad rolling stock made imperative design changes wherein wood was largely supplanted by steel. Builders were faced with a transition period and a readjustment of men, methods and machinery.

Today the economies of railroad operations make necessary a change to a lighter weight equipment in which newly developed alloys of thin gage are used and as a result the builders are faced with fabrication by welding instead of riveting. Welding is also being specified on standard weight cars. Again there is a transition period and a readjustment of men, methods and machinery.

Today the car builders have the problem of supplementing or replacing the riveting hammer with the hand-welding torch, and the hydraulic riveter with the automatic arc welder or spot welder.

The welded tank-car tank is not, as is generally supposed, a strictly modern product. The welded car tank has had quite a checkered career. Car foundry experience in welded tank-car tanks dates back all of 30 years, in fact almost as far, if not further, than the extensive use of welding in other types of railway equipment.

Any structure or element of a structure that is a part of a railway car is subjected to vibration and a greater variety of shocks than are found in any permanent structure, be it building, bridge or the enormous stills used in the petroleum cracking process.

Let us first try to visualize what advantages a welded tank-car tank would or could have over that of a tank in which the seams are joined by means of riveting. The first point would be that, for equal strength, the tank could be considerably lighter. Where and why could it be lighter?

Now let us take an 8000-gallon riveted tank, per I. C. C. specification 103. If the inside diameter of this tank is not over 78 inches then the bottom sheet must have a minimum thickness $^{7}/_{16}$ inch—the head must have a minimum thickness of $^{1}/_{2}$ inch, while the upper shell sheet need only be $^{5}/_{16}$ inch.

This tank is designed with a seam strength having a theoretical bursting pressure of 300 lb. per square inch. Inasmuch as the actual strength of this seam is only 70% of the value of the $^{5}/_{16}$-inch top plate, therefore, with the assumed 90% welded seam strength the plates could be made thinner. However, the new I. C. C. specifications maintain the $^{5}/_{16}$-inch upper shell sheet thickness in the longitudinal seam-type welded tank which, experience has shown, is needed to furnish the desired stability of the tank rather than the bursting strength.

You will ask why we could not make the heads and bottom sheet thinner. The reason that the bottom sheet is made $^{7}/_{16}$ inch is because experience has taught us that if we thin up on this sheet we are liable to have a failure of the bottom sheet over the bolster slabbing. I might say that earlier tanks had thinner sheets and we found there was trouble around the slabbing caused by crystallizing and cracking. Many of the old tanks had patches applied where the tanks rested on the slabbing. The entire weight of the tank and the lading is carried by the bottom sheet where it bears on the slabbing. We may also experience trouble where the tank anchor is secured to the bottom sheet. The function of this anchor is to keep the tank from shifting longitudinally on the underframe.

The tank heads are made $^{1}/_{2}$ inch thick because the heads are subjected to excessive stresses due to the surging of the lading caused by sudden stops of the car in transit. By welding the tanks seams we do not lessen in any way these abnormal shocks due to transit and therefore the welded tank must have the same thick-

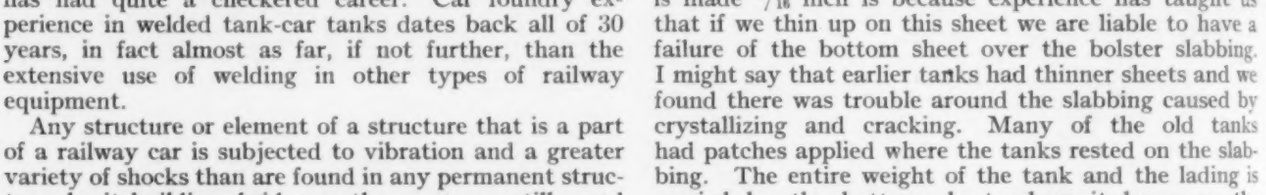

Fig. 1—Six Compartment Insulated Tank Automatic Fusion Welded

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Electrical Engineer, American Car and Foundry Company, New York, N. Y.

Fig. 2—Automatic Fusion Welding of Interior Head Seam

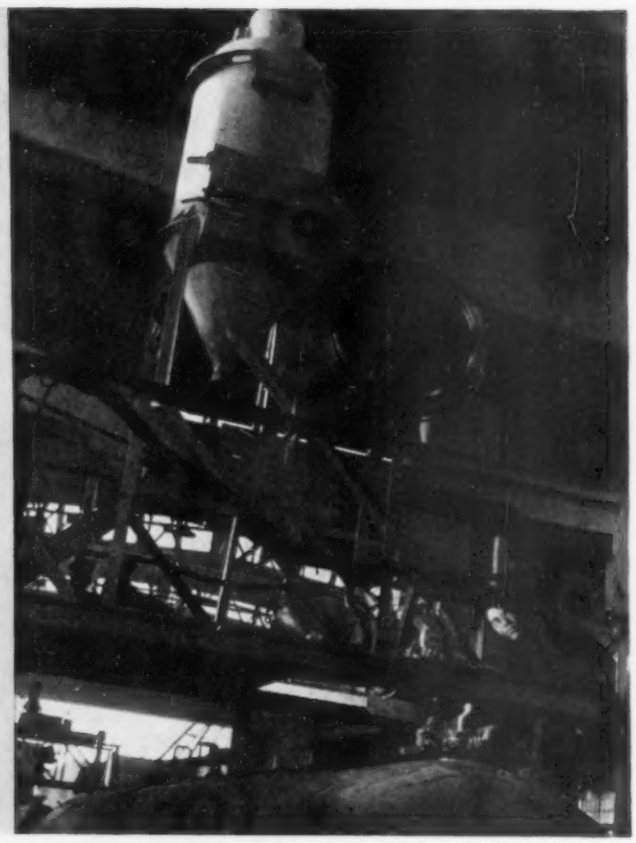

Fig. 3—Automatic Fusion Welding of Exterior Head Seam

ness bottom sheet and head sheets as required by the riveted tank.

The overlapping of the seams is eliminated and therefore narrower sheets may be used. The rivet heads are eliminated which entails a saving in weight and cost in that the proper way to join the sheets in the welded tank is by butt welding.

When we come to the Class ICC-104-A and ICC-105 types of car, where the figured internal pressure is such as to be the governing factor in determining sheet thickness, there may be a reduction in thickness when the tank is fabricated by means of welding, extending over the entire tank.

The uniform thickness of shell of the welded type of construction is not possible with the riveted type. Where the sheets forming the riveted seams overlap, there is a rigid band, so to speak, both longitudinally and circumferentially around the tank. You might ask what bearing this has on the subject.

Any tank built out of thin sheets such as is permissible in the ICC-103 group of specifications, breathes—that is, when it is not loaded or only partially loaded but not under pressure, the tank is not cylindrical but elliptical in cross section.

If we have a uniform thickness of tank shell this breathing will be uniform to a large degree over the entire cross section of the tank. Where the section is not uniform, that is, where the tank has these rivet seams or bands, there is an unequal distortion of the metal due to this breathing which has a tendency to open up the joints and start leaks.

With a riveted tank, that is, not fabricated according to the very best practice, leaks do develop in these riveted seams. On the welded tank, assuming that a good job of welding is done, there is no danger from the standpoint of leaks.

Another advantage of the welded tank over the riveted tank is that in the welded tank we have a relatively smooth interior. There are no rivet heads projecting. This is especially desirable for tanks which are to be lined either with lead or, more especially, with rubber, or even with some of the spray materials. From the above you can see that there are quite a number of advantages in the welded tank over the riveted tank. Not so great in connection with the ICC-103 or the ICC-104 tanks, but of material advantage in the ICC-105 group of tanks having heavier shells.

The statement has been made that the welded tank is more expensive than the riveted tank. This is to be expected as it is necessary to explore all these welds by the X-ray process and then stress relieve the entire tank as a unit; the additional cost of these two operations puts quite a cost burden on the welded tank and makes its first cost considerably higher than that for the riveted tank.

In tank-car tanks, we find three distinct types of welding, namely,

1. Forge welding such as is used by A. C. F. affiliate, the American Welding Company.
2. Gas fusion welding.
3. Electric fusion welding.

I am advised that during the 1880's Mr. T. F. Rowland evolved the idea of roll welding. In order to make this a practical method of fabrication it was necessary to design and build special machinery.

During the 1890's Mr. C. L. Rowland went to Carbondale, Pa., where he established the American Welding Company. Probably the earliest application of this

method of forming tanks used on cars is the one-ton liquid chlorine container, now used for the ICC-106 group of cars.

During the World War, our Government was confronted with the necessity for safe transportation of large unit shipments of liquid chlorine to be used in the manufacture of deadly gases. To meet this situation the large forge-welded tank known as Class 105 was developed. There have been many improvements in the design of this tank since that time and there are today more than 1200 tanks fabricated by the forge-welded process in service on American railways.

The forge-welded cars, while being principally used in transportation of liquefied chlorine, are also used in the transportation of liquefied petroleum, anhydrous ammonia, metallic sodium and other products.

The general term fusion welding as used in connection with tank-car tanks may be defined as heating two pieces of metal that are to be joined, up to the melting point and filling in the space between prepared edges with molten metal. This is true of both the gas and the electric arc processes.

Considering the second type of welding, that is, the use of gas:

In 1908 A. C. F. built four railway car tanks using gas welding, and for filler metal we used scraps from the steel plates. These were for Peru. To the best of our knowledge these cars have given very satisfactory service.

Some years later one or two experimental tanks were gas welded, but the trade was not ready for welded tanks.

Let us now consider the fabrication of tank-car tanks by the electric fusion method. After a long uphill struggle extending over a number of years the I. C. C. granted authority for the construction of a limited number of tanks of the electric-fusion type. In the first authorization (November 13, 1935) were included cars of the ICC-103-B (that is, rubber lined) for the transportation of acid. In April 1936 authorization of the ICC-105, ICC-103-C (that is, for nitric acid) was given.

In the beginning all of the tanks built under I. C. C. authorization were of the barrel type, that is, the tank shell is built up from rings. This is the proper way to build a tank of the ICC-105 type, also ICC-104-A, but for the ICC-103-B type the tank is considerably heavier than the usual riveted tank meeting this specification. Why? The reason for this is that with the barrel type of tank the thickness of the entire shell must be that of the bottom sheet and no advantage can be taken of the permissible use of thinner top sheets.

Up to date there have been upward of 1085 of the fusion-welded type tank-car tanks authorized by the I. C. C. The latest records which we have had access to show that something over 491 of these tanks have been built and put into service.

The permanent specifications, recently recommended by the A. A. R. Tank Car Committee to the I. C. C. in the authorization for the construction of fusion-welded tanks, require Class 1 welding, that is, after the tank has been built, all of the seams must be explored by means of the X-ray and the tank, in its entirety, must be stress relieved. These specifications for welded tanks cover all those in the 103, 104, 104-A and 105 groups.

There have been tanks built under A. A. R. authorization for non-regulatory commodities which do not carry this X-ray and stress-relieving requirement. These tanks have given a good account of themselves in transportation service.

Facilities for welding of the latest developments have been installed in the past two or three years at our tank car plant at Milton. A stress-relieving furnace was installed of the car type large enough for any standard design of tank car-tank, equipped with 24 oil burners pyrometrically controlled with Minneapolis heat controls. The furnace has two Leeds & Northrup 2-point recorders. Stress relieving is done at 1150 to 1200° and annealing at 1500°. Heating is restricted to 400° per hour above 600° per inch thickness or less. Vessels are held at a maximum temperature one hour and allowed to cool at 300° per hour per inch thickness.

X-ray is done with a 200,000-volt machine, technique is checked against A. S. M. E. radiographs and penetrometer gages, the welding process gives about $^1/_{16}$-inch reinforcement which requires no chipping or grinding due to its uniformity. Stereoscopic locating depths and X-ray pictures are also available.

A 100,000-lb. tension-test machine was installed in order to make such physical tests as are required.

The developing of production methods and installing production welding equipment which will give a normal production, and a quality of output through fabrication by welding, equivalent or better than the present methods of riveting were a problem for our company.

The application of automatic or machine welding dates back to 1924 when our first installation was made for the welding of small gas tanks in the pressed steel department at our Milton plant. Since then, additional installations at other plants have been made for welding (*a*) mine cars, (*b*) hopper cars, (*c*) 8th Avenue Subway car roofs.

The use of automatic arc welding arises from the desire to obtain the following results:

(*a*) Greater economy in labor and material.
(*b*) More uniform results.
(*c*) Greater operating factor.
(*d*) Higher welding currents which in turn measure greater production.
(*e*) Reduced fatigue on operator.

Automatic arc welding is particularly adapted to high production welding where there is a large number of similar operations or where there is enough footage of the same type of welding to justify, in which case you can afford a fairly expensive holding or clamping fixture.

A. C. F. having installed several automatic or machine-welding processes which installations have been approved by the A. A. R. Tank Car Committee, are in position to offer its customers any approved process they may prefer; the process producing the most economical tank will probably be selected.

Quality resulting from the equipment requiring the smallest number of cut-outs as indicated by the x-ray inspection becomes our recommendation.

Our welding facilities at the Milton plant in the last several months have produced about 240 welded tanks by the several processes.

I will now describe:

(*a*) The "Unionmelt" process used for the several classes of steel tanks.
(*b*) The shielded automatic carbon arc process as used in the construction of aluminum tanks.

(*a*) "Unionmelt" welding is an electric process using the heat generated by the passage of an electric current from an electrode to the work being welded. The end of the electrode is constantly covered by a highly resistant, conductive medium supplied as a special granulated material or welding composition.

This granulated material is laid down along the seam to be welded and the entire welding action takes place beneath it, without an open, visible arc, and without sparks, spatter, smoke or flash. Within the layer of granulated material an intense, concentrated heat is

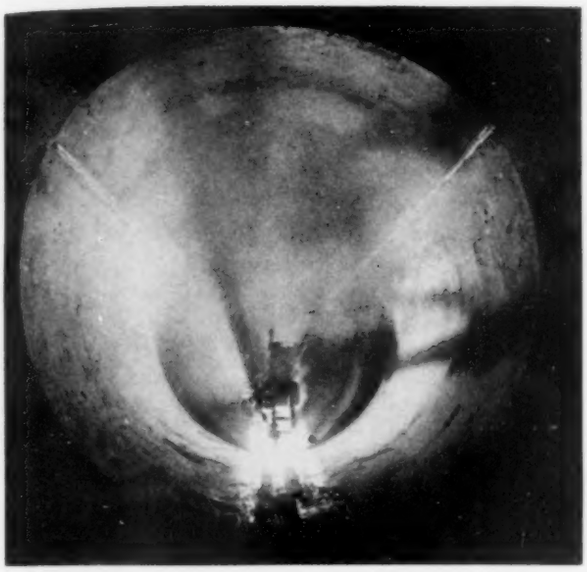

Fig. 4—Carbon Arc Automatic Welding of Aluminum Shell Longitudinal Seam

generated by the electric current, and the bare metal electrode and a portion of the edges being welded are melted and fused. Molten metal from the electrode is thoroughly mixed with the melted base metal to form the weld. When a weld is being made, a sub-surface layer of welding composition melts and floats as a liquid blanket over the molten weld metal.

This welding composition performs several important functions. It makes possible the use of higher current densities than for other welding methods. This permits the rapid generation of the intense heat which melts the metal. It is a good heat insulator and thus concentrates the heat in a relatively small welding zone. It acts as a cleanser for the weld metal, washing the metal which melts from the rod and absorbing impurities from the fused base metal. Consequently, the weld metal is exceptionally clean and dense, and has excellent physical properties, unusual for large weld-metal deposits. Though the constituents of welding composition do not normally enter into the weld metal, special alloying elements can be introduced into the weld metal, by means of this material.

In operation, this welding process is fully automatic. Since the granulated material is not a conductor of electricity when it is cold, a special "fuse"—a wad of steel wool, for example—is used to start the weld. The fuse is covered with welding composition and, when welding current is turned on, the fuse becomes sufficiently hot to melt the adjacent layer of granulated material, which permits the welding operation to continue. The welding composition is progressively fused by the heat generated as the weld proceeds.

Bare welding rod is continuously fed from a special rod reel into the welding zone by an automatic welding head. Welding composition fed through the welding head is progressively laid down along the seam to be welded a few inches in front of the rod. Since only part of the granulated material is fused during the welding, the unfused material is picked up, usually by a special "vacuum cleaner," type machine and returned to a hopper for re-use. The fused melt solidifies behind the welding zone and, on cooling, contracts and detaches itself, exposing the clean, smooth weld.

Welding voltage, current, speed and rod feed are all automatically regulated by electrical controls. Welding voltage is held at the predetermined value by the adjustable, automatic voltage control which governs the rod feed. Voltage, current, speed, rod feed and rod size depend on the material being welded, its thickness, the type of edge preparation being used, the depth of fusion desired and the shape and reinforcement of the weld specified. All of these factors can be regulated within practical limits.

The operator merely pushes buttons and adjusts controls. Aside from the continuous feed of the welding electrode and the movement of the welding head, there is no visual evidence that a weld is being made.

The process will make butt welds, fillet welds and plug welds of desired practical penetration and contour in commercially used thicknesses of material. Although this process is especially advantageous where the operation is repetitive, it is in wide use for welding miscellaneous single unit structures and can be used where welds can be made with the surface of the welding puddle approximately horizontal.

For making butt welds in one pass, where complete penetration is desired, the weld must be backed to prevent the fused metal from falling through. A copper bar, a sliding copper shoe or a trough of granulated material have all been successfully used for backing butt welds. When granulated material backing is used, a fairly smooth bead, somewhat similar to that on the top surface, can be obtained on the bottom surface of the weld.

A fixed or rolling copper ring and a sliding copper shoe have been successfully used for backing circumferential butt welds in pipe and other cylindrical products. Steel backing pieces which may remain permanently attached to or may be cut from the under part of the finished weld are sometimes used. A relatively light unbacked weld made from one side of the joint is also extensively used to serve as backing for the main weld.

These two-pass welds, with one partly penetrated weld from one side serving as backing for a deeper overlapping weld made from the other side, are particularly advantageous for the usual pressure vessel, tank, boiler and other non-production work which does not justify special backing equipment which would be necessary if one-pass welds were to be made.

Although large wall cranes and gantry cranes carrying one or two welding heads are in use in several plants and although the large installations offer unquestionable advantages for certain classes of work, smaller, more portable units are being used in our shops for railroad car tanks and similar structures.

In fabricating tanks both longitudinal and circumferential inside welds are made as the various courses are assembled. A type U head and rod reel is used mounted on a special motor-driven carriage, having a variable speed control. This carriage does not require track. The steering of the head is accomplished by a three-wheeled pilot, or guiding device, which rides in the V groove ahead of the welding zone.

The circumferential welding is accomplished by setting the carriage parallel to but offset from the circumferential seam and synchronizing the inches-per-minute travel of the carriage with that of the rotator. In other words, the carriage will travel at exactly the same speed in the opposite direction to that of the rotation of the shell thereby holding the Unionmelt head in approximately a fixed vertical position. This application has eliminated entirely all hand welding on the inside of the shell proper.

On 103-*W* and 104-*W* tanks, all of the shell and head seam are completely welded before the domes are applied and there is ample room to take the welding unit in and out of the dome cut-out opening in the top sheet; on

105-*W* tanks it will be necessary to remove the reel and take the equipment in and out the tanks in two units.

The type S unit, which has about half the capacity of the type U and feeds only straight lengths of rod, is small and readily portable; this unit therefore becomes adaptable for plug welding inside a welded tank where punched flanged heads are installed to divide a single compartment tank into three to six compartments.

The type S unit has also been applied to the fabrication of code air-receiver tanks; both the longitudinal and circumferential seams are butt welded with a backing-up strip on code tanks.

When a customer specifies the use of multi-pass welding on the fabrication of an order, automatic arc-welding equipment is used for the longitudinal and circular seams of the tank. This equipment through its automatic feed-welding head deposits a $^1/_8$-inch ribbon of heavy-coated electrode as the tank revolves on its rotator until the groove has been fully penetrated. Careful cleaning of slag or flux between each pass is necessary.

(*b*) The automatic carbon arc welding in the construction of aluminum tanks at our Milton plant requires filler metal, flux and the arc.

The advantages of shielded carbon arc welding by the Electronic Tornado are readily apparent since this process practically eliminates the human element. Virtually nothing is done by hand. The arc is automatically struck, shielded and maintained at constant length. The carbon electrode is automatically fed and rotated to preserve a symmetrical point. Filler metal can be automatically added where needed.

Other advantages are to be noted in the manner in which the carbon arc operates. The arc is formed between the plates to be joined and a carbon electrode. The carbon electrode moves along the seam, fusing the edges of the plates. Directly underneath the arc is a molten pool of metal. The two plate edges are fused simultaneously and cool simultaneously. The weld is made by puddling rather than by deposition of electrode metal. Where extra metal is required to reinforce the weld, it is added in the form of a filler strip. This filled metal is not a part of the welding circuit.

Inasmuch as the weld is made by puddling rather than by the deposition of metal, splatter is practically eliminated. Hence, the carbon arc lowers costs by minimizing cleaning of the work after welding.

The automatic process permits faster construction and a considerably better quality weld together with marked freedom from distortion. This development was motivated by a desire to improve the quality, not to lower costs which are practically unchanged due to the increased flux cost cancelling the labor saving.

Since no beveling of plate edges is required, the full thickness of metal is utilized in the welding by simply butting the square edges together, greatly simplifying the set-up of the work. The welding time per tank is noticeably shorter than previous methods since the automatic weld is made in two passes instead of three formerly used. The fact that two-pass automatic welding permits welds of complete overlapping penetration accounts for the greatly improved quality of the weld.

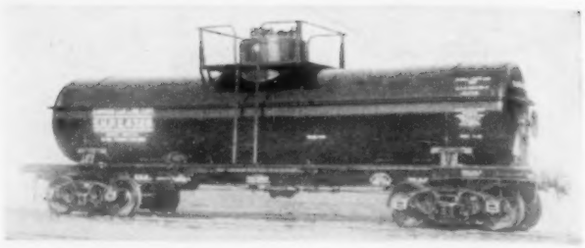

Fig. 5—Single Compartment Uninsulated Fusion Welded Aluminum Tank

Freedom from distortion, which has been a factor in previous methods of fabricating aluminum, is permitted with the automatic carbon arc method because of faster welding. Very little straightening is required on round tanks welded by this process whereas with the previous method considerable straightening was necessary. This advantage not only simplifies production of the shell itself, but, because the shell is so uniformly round, the heads are readily fitted to the ends of the shell.

Materials used in constructing tank cars of aluminum include: a bottom plate $^5/_8$ inch thick; two sides, or top, plates $^1/_2$ inch thick; and two heads $^5/_8$ inch thick. The tanks are 78 inches outside diameter and 32 feet over-all length.

Square-edge tight butt welds are used throughout in construction. The difference in thicknesses of the butting edges is taken care of by maintaining uniform outside diameters and making up the difference by an offset on the inside of the tank.

Three longitudinal welds, two consisting of $^1/_2$ to $^5/_8$-inch and one of $^1/_2$-inch thickness, are required in constructing the shells. Two passes, one inside and one outside, are required for each longitudinal seam. The first longitudinal pass is made on the inside with the seam properly backed up with a water-cooled copper chill bar, giving complete penetration with one pass. The second pass, made on the outside, is applied to obtain overlapping penetration and for the sake of appearance. It is made without any backing up.

In welding the heads to the shell, the head is fitted and the tank rotated under the carbon arc which welds the outer seam with the inside properly backed up with copper chill bars. Filler metal for the weld is supplied by $^1/_4$-inch aluminum wire fed into the arc. The second pass on the head weld is done manually after grooving with a chipping tool.

The aluminum tanks manufactured by our company have for the most part been utilized for glacial acetic acid service. This is the basic material for the manufacture of rayon and non-inflammable film. Two of the aluminum tanks have also been put into service for carrying peroxide. These were constructed of 2-*S* (99.5% aluminum). The balance of the tanks, for acetic acid service, were constructed of 3-*S* aluminum (97.5% aluminum).

21st ANNUAL MEETING, A.W.S.

The 21st Annual Meeting of the Society will be held at the Cleveland Hotel, Cleveland, Ohio, during the week of October 20th, in conjunction with the National Metal Congress and Exposition. There is every indication that the attendance at the show and technical sessions will surpass all previous records. Finest collection of papers ever presented will be given. No one identified with the welding industry can afford to stay away. Make your reservations early. Hotel practically sold out.

SILVER AND ALLOY SOLDERING*

By CHARLES F. ZAPPONE†

IT IS a popular misconception that silver and associated alloy soldering is a comparatively new development of industrial application. As a matter of fact silver and silver alloys were in common use in the Guilds of the Silversmiths and Coppersmiths in the Middle Ages.

Modern industrial fabrication with its component requirement of high-speed production created a demand for a ductile soldering alloy with a comparatively low melting point and comparatively high tensile strength. Silver solder, in its various alloy combinations, has been the answer to this demand. These new alloy combinations have served many manufacturing needs, but in no industry has it been of greater value than in the thermostatic field. The great change in the thermostat manufacturing method and design from the rigid couple type thermostat to the flexible hydraulically operated thermostat created an immediate demand for a flexible, yet strong, container and retainer for the hydraulic fluid. Copper, stainless steel, brass, cold-rolled steel, just to mention a few, are metals that can be and have been successfully used as containers for the hydraulic fluid. However, each of these metals has required some type of seal at the various joints and at the point at which they are charged with the activating fluid. A definite problem has been created here because it has often been necessary to seal together entirely dissimilar metals, such as copper and stainless steel. Silver solder is the only metallic sealing device which has had a universal application for this purpose.

In the industry where the speaker is engaged the application of new methods created a demand for approximately 40,000 ounces of silver solder annually in the three plants engaged in the work. The use of this alloy of course, created a specialized demand for skilled workers. It was discovered that none were available with training in the work and, consequently, they had to be trained in actual operation at the plant performing the work. Time does not permit a detailed discussion of the training method, but should any of the listeners be interested they may find a complete account of it in the February 1939 issue of *Factory Magazine*.

Utilization of silver solder and method of application can best be demonstrated by actual views of the work being done.

Figure 1. Good equipment is of primary importance in good work performance. All oxygen for torches used in the work is supplied from the ten-cylinder manifold set-up shown here. Acetylene from a six-cylinder manifold and natural gas are piped to the stations of operations thus insuring uninterrupted operation for maximum efficiency.

Figure 2. The shop is arranged for straight-line production. Primary operation begins with the operator at the spot welder nearest the audience. Silver solder plays an important part in the operation of this machine as will be shown in later views.

Figure 3. When a unit has completed the journey through this production line it will be similar in appearance to the one shown. Simple as this part may seem twenty operations have been performed on the production line shown including four silver solder operations. This total number of operations does not include operations required in other departments to fabricate the parts.

Figure 4 shows the first silver soldering operation performed in the thermostatic unit. Production on this operation is approximately 500 pieces per hour. The jig shown revolves. The piece also revolves at the station in front of the operator. This enables the operator to use a much larger torch tip without damaging the copper tubing and consequently to maintain a high speed of operation. A number 4 tip is used in this work. The operator controls the rate of revolution of the jig by means of a foot treadle. The man standing loads and unloads the machine.

Figure 5 gives a concept of the size of the parts being silver soldered on the operation just shown. The smaller diameter tube is a capillary. Its diameter is 0.093 inch O.D., 0.031 inch I.D. The larger tube is the bulb with a diameter of 0.164 inch O.D. 0.094 inch I.D. The end of the bulb has been swedged so that the capillary will fit in its inside diameter with a clearance of 0.001 inch. The capillary is inserted into the bulb for one-half inch and silver solder is "sweated" $^3/_{16}$ inch into the joint. Previous to the soldering operation both parts are precleaned in carbon tetrachloride and baked for two hours at a temperature of 350° F. This rids them of all grease and moisture which might otherwise cause pinholes and be detrimental to the operation of a hydraulic unit. The pencil in the foreground will give a visual idea of the size of these parts. The parts are shown both assembled and soldered and unsoldered. The white area at the joint is the exposed silver soldered area.

Figure 6 is a picture of the second silver solder operation in which the copper capillary tube is soldered to a stainless steel stud. The jig shown is automatically revolved and controlled by the operator.

In the close-up view of Fig. 7 you can better see the size of the joint being soldered. There are some factors important to bear in mind in the silver soldering of stainless steel. Stainless steel has a high rate of oxidation at elevated temperatures. Thus, it is necessary to perform the silver soldering operation as rapidly as possible when the proper temperature is reached. Ordinarily, in soldering larger joints the proper temperature would be determined by waiting for the flux to melt, but since in a joint of this size the melting point of the flux is almost coincidental with the proper temperature in the stainless steel, visual observation of the temperature of the steel must be used; that is, the operator must note the temperature coloring of the steel. It has been determined that the best soldering temperature is indicated when the blue coloring is leaving the steel and just before it turns a dull red. Experiment has shown that this coloring cannot be determined in strong sunlight or daylight and that many types of artificial light are also unsatisfactory.

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Supt. of Welding, Robertshaw Thermostat Co., Youngwood, Pa.

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It was finally discovered that mercury vapor light best served the needs of this operation. You can see in the background one mercury vapor lighting tube. Another not visible is just above and to the left of the operator. This light also has the advantage of casting no shadow and of subjecting the operator to a minimum of eye strain. Since the production of this job is approximately 500 pieces per hour the matter of eyestrain demands careful consideration.

When the operation in Fig. 8 is performed the element or unit has been filled with the activating liquid and the open end of the bulb through which the liquid has been introduced is being sealed with silver solder. There are some special factors in the construction of this jig that deserve attention. You will note the air cylinder at the bottom center of the picture. When heat is applied to this liquid-filled bulb there is a softening of the metal and at the same time an expansion of the liquid. If the crimping jaws which are activated by the air cylinder were mechanically operated the liquid would be able to force a passage through the crimp due to the softness of the metal. However, the air cylinder maintains a constant pressure and as the metal softens under the heat of the torch the seal in the crimp is maintained.

In this close-up view of Fig. 9 several other elements in the construction of this jig can be seen. The small tube leading down to the work is an airline. It is regulated by the operator from a foot valve and serves to blow the excess fluid out of the tube above the crimp. The larger tube in the background is an exhaust tube which draws the fumes away from the operator. This is necessary because of the irritating qualities of the vapor from the liquid used to fill the bulb. The hole sealed in this operation is approximately 0.080 inch I.D. and $^1/_8$ inch in length. The operation is performed at a rate of 200 pieces per hour. In routine inspection of this operation each and every piece is ground, etched with nitric acid and inspected under a magnifying glass.

This operator in Fig. 10 is silver soldering a brass bushing to an invar rod. When all the pieces in the jig have been completed the jig is tipped over by hand and the pieces fall out. Oxygen and natural gas are used on the operation. This is done because the heat must "soak" through the brass to the invar. Brass has a comparatively low melting point as compared to invar. If an oxygen acetylene is used in place of the softer oxygen natural gas flame the brass would reach the soldering temperature before the invar had been properly heated and a poor joint would result.

You will be able to see from Fig. 11 the size of the pieces being soldered in this operation. The large cylinder in the foreground is a regular size pencil. In this photo I also want to direct your attention to the flange and nipple. The brazing operation performed on them will be shown next.

The flange and nipple being brazed in Fig. 12 are of cold-rolled steel. A manganese-bronze brazing alloy is used for this operation. As the operation is completed the operator tips the part into the chute and it will fall into the bucket of water. This water quench determines the difference between a successful and an unsuccessful joint. If this part were allowed to air quench the hardening of the bronze would cause it to crack. The water quench increases the ductility of the bronze and makes a successful joint.

The solder used on the operation of Fig. 13 is a "happy-medium" between a high- and a low-temperature solder. Its composition is $97^1/_2$ per cent lead and $2^1/_2$ per cent silver. Its melting point is 575° F. The oxygen natural gas flame is also used on this job. Both of these things are done because of the nature of the piece being soldered. It is a bellows of spring brass 0.005 inch thick. One pass of a torch would be sufficient to burn a hole in the wall of this part. The jig shown plays an important part in the success of this operation. The operator opens and closes the jig with a foot pedal. When the brass bellows are in the jig they are completely enclosed in a water jacket to aid in heat dissipation.

Figure 14. The bulb end of special elements are sealed with silver solder on this jig. The jig itself is of copper. This metal is used in order to aid in dissipating the heat of the torch. On the particular job being performed the operator is silver soldering a steel bulb with a 0.015-inch wall. The copper backing in the jig prevents the steel from becoming heated too rapidly. This gives the operator sufficient time to make a good joint without the hazard of oxidation.

The jig shown in Fig. 15 is used for maintenance work on our own equipment. Elkonite inserts are silver soldered onto the electrodes of our resistance-welding machines by this operator. The Elkonite inserts are placed in the electrodes prefluxed and soldered into position. The electrodes revolve in front of the operator so that he may solder the joints on the entire circumference.

Figure 16 shows some of our most commonly used electrodes with Elkonite inserts soldered in place. The electrode on the left has a male insert, the one in the center has a female insert. Both of these electrodes are used in spot-welding operations. The electrode on the right has an Elkonite ring soldered around its circumference. This electrode is used on a seam-welding operation.

Figure 17 is another of our maintenance silver-soldering operations. In this work tungsten carbide tips are silver soldered to cutting tools. The tool tip is preground for soldering operation and washed in carbon tetrachloride to remove all grease and moisture. The tip must be untouched by human hands after the cleaning operation since the slightest moisture or grease from the human body might prevent a good bond in the soldered joint. Strip silver solder is used for this work and is placed in the joints prefluxed. Heat is then applied a short distance back of the tip until the flux melts. The flame is then applied directly on and under the tip with the torch being kept in constant motion.

Figure 18 is an electric thermostat. The contacts and wires on this thermostat are silver soldered.

Figure 19 is a popular model of safety pilot. Joints, bellows and tube all have silver-soldered connections.

Figure 20 shows cutaway models of leading production models of thermostats.

Figure 21. Most of our work is being done with a silver solder of the following specifications: 50% silver, $15^1/_2$% copper, $16^1/_2$% zinc, 18% cadmium. The melting point of this alloy is about 1175° F. We also use numerous other silver-soldering alloys where color harmony and electrical conductivity are important factors.

In conclusion I would like to show you the development in thermostatic design.

Figure 22. The thermostat on the left was the last word in thermostats in 1899. The one in the center is the highest stage of development of the solid couple type thermostat. The one on right is the compact, streamlined, highly efficient product of today. It is only through the development of a practical low-temperature brazing alloy that this hydraulically operated product is possible. I would like to express my appreciation to Mr. Ames and Mr. David of the Air Reduction Sales Company for their cooperation and assistance in the making of the illustrations used during this address.

FLAME HARDENING*

By R. H. ZEILMAN†

GENERAL

THE subject with which this paper deals is flame hardening, as it is applied to excavating machinery in our production of this type of equipment. By excavating machinery, I mean the type that employs an excavating bucket to dig the material and load it into a carrier, or deposit it in the desired spot, as the case may be. Such equipment is represented by power shovels, draglines, clamshells, back hoes, etc.

Excavating equipment embodies a number of large, heavy parts, some of which are subjected to abrasive wear, and in many cases the wearing surface of these parts is relatively small. To protect against wear, these surfaces must be hardened. It is often impractical, and even undesirable, to harden the entire piece. Such hardening, to successfully resist wear, would leave the part entirely too hard to withstand the impact to which it is subjected. The alternate is to reduce the hardness, provide the necessary impact values and sacrifice wear resistance. Flame hardening has made it possible to locally heat treat such parts quickly and economically, without sacrificing either the ability to resist wear or shock.

We employ flame hardening for two reasons; the first being to provide a product well able to withstand the severe usage to which excavating machinery is subjected, and, second, to take advantage of the economies which hardening by this method provides.

Of the several methods of flame hardening in common use, we have found the so-called progressive method the most adaptable, and nearly all of our work is done in this manner. This method consists of heating progressively by an oxyacetylene flame, moving at a uniform rate of speed over the area to be hardened. The surface of the metal is thus brought to the proper temperature and a closely following water spray quenches the heated area immediately. Either the torch or the work may be in motion.

Figure 1 shows a plan view of the upper deck of a small excavator. This photograph is shown to illustrate some of the parts which we generally flame harden. Here can be seen the bevel rotating pinions and gear, the bevel propelling gears, sliding jaw clutch and the cone rollers on which the upper deck revolves. Other items, not shown, which are hardened, are the roller path for these rollers, wear blocks which guide the dipper stick, the shrouded spur pinion which actuates this dipper stick, rope sheaves and a number of miscellaneous other items. In all, about 90 different parts that go into excavators are being flame hardened.

BEVEL GEARS

Figure 2 shows the hardening operations on a bevel swing pinion. Here, the teeth only, are hardened by the use of a two-flame flexible type tip with a separate quenching attachment. The torch is mounted on a motor-driven machine traveling at 6 inches per minute. Alternate teeth are hardened the first time around the gear. The second time around, the remaining teeth are hardened. An additional stream of water is directed on the hardened teeth to prevent any drawing of these teeth, from the residual heat. These pinions are hardened as they come from the foundry and before any machining operation.

A previous design of a swing bevel pinion and clutch drum assembly is shown in Fig. 3. The purpose of showing this construction is to illustrate how the use of flame hardening frequently permits product improvement which otherwise would require costly redesign. Here the bevel pinion is furnace hardened and pressed onto a steel hub. The hub is bronze bushed in its bearings on the shaft. With this construction it would have been impossible to substitute roller bearings for the bronze bushings, except by increasing the diameter of the pinion and thereby necessitating a major redesign. Figure 4 shows how the incorporation of roller bearings was accomplished economically, through the use of flame hardening. Here the hub and gear were made integral, thus providing space for roller bearings, and by flame hardening the gear teeth it is possible to accomplish machining on unhardened metal. It will also be noted that the ends of the teeth connect into the flange in one case, and into the shroud in the other, thereby producing a shrouded effect. These shrouds serve to strengthen the gear teeth so that the base metal, without heat treatment, produces the requisite strength.

The flame-hardening operation on a bevel propel gear is shown in Fig. 5. Here, the gear teeth are being hardened in the usual manner, with the torch mounted on a motor-driven machine and traveling at 6 inches per minute. Water-cooled, block-type gear-hardening tips are attached to a flexible assembly, and, as the torch progresses toward the heavy end of the gear tooth, a cam separates the tips, so that the distance between the tip and the work surface remains constant. Figure 6 shows the gear that was being hardened in the previous photograph. It also shows the integral jaw-clutch lugs, which are flame hardened on their driving surfaces, in another operation. The hardening is done on this gear after all machining operations, as the hardening of the jaws would render certain surfaces, requiring finishing, too hard to machine. While the hardening of the gear teeth is a separate operation, and could precede all machining operations, in order to avoid an extra handling, the part is completely machined, then sent to the hardening department for treating.

A small pinion with an integral jaw clutch, similar to the gear previously shown, is being hardened on the teeth in Fig. 7. The set-up is the same. It will be noted that this pinion has a shroud at the small end. It is, of course, difficult to extend the hardened zone entirely to the shroud, and no attempt is made to do so. In fact, it is desirable to leave an unhardened area adjacent to the shroud to insure against any hardening

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

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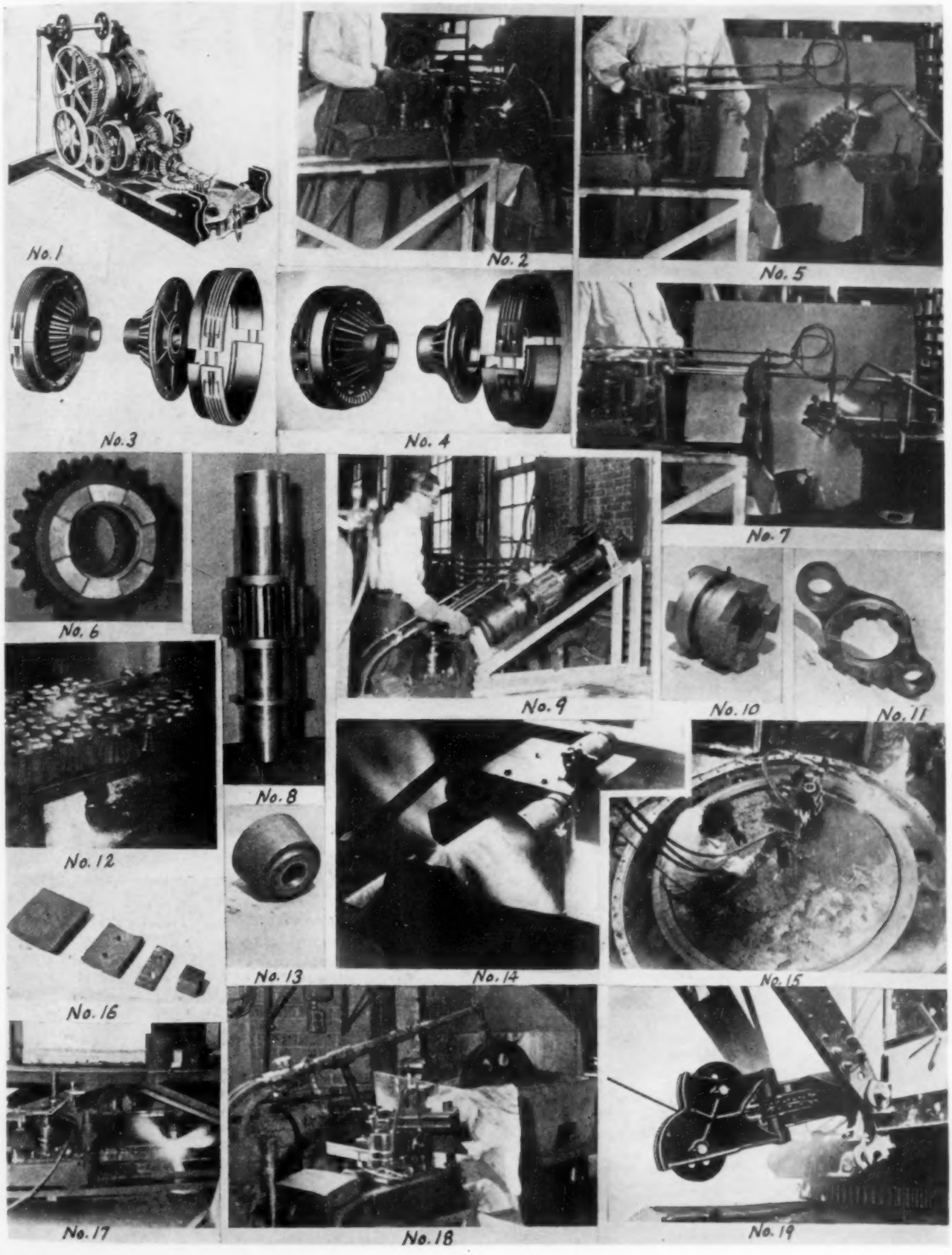
cracks at this point. As in the previous photograph, a separate cooling spray may be seen. This spray is directed on the last tooth hardened to prevent the flame from drawing the hardness of that tooth.

SPUR GEARS

The flame hardening of spur gears has not been practiced to any great degree by our company. The reason



being that usually gears which require hardening to resist wear also require higher physical properties than exist in the untreated material. In many cases, we find that satisfactory wear resistance occurs when the parts are furnace hardened to produce the requisite tensile strength. So, for economy, we limit the treatment to furnace hardening after machining.

Figure 8 shows a spur pinion which is an exception. This is the shipper shaft pinion, or the pinion which directly actuates the dipper stick. Beside high tooth pressures and stresses, the teeth of this pinion are subjected to what amounts to severe misalignment, as the dipper stick weaves and twists during the digging cycle. The resulting high unit pressures require a surface hardness greater than can normally be had with the most desirable physical properties in the base metal. In other words, if the entire piece were hardened so as to produce the necessary wear resistance at the tooth face, it would be too hard to withstand the impact to which it is subjected.

The hardening operation of this part is shown in Fig. 9 and is the same as is normally used on spur gears. The pinion is mounted on cone centers at an angle of 30°. It will be noted that this pinion has half shrouds, and, if it were mounted in a horizontal position, the quenching water would dam up at the shrouds and run ahead of the flame, interfering with the heating. Therefore, the work is tilted, allowing the water to escape back of the tip. The torch is mounted on a machine driven at 5 inches per minute by a variable speed motor. The torch is guided so that it travels parallel to the axis of the work, and the distance between the tip and the gear tooth remains constant.

The half shrouds, previously referred to, roll in contact with corresponding shrouds on a drop-forged, hardened rack, which is, in turn, attached to the dipper stick. These surfaces are also subjected to high pressures and require a high degree of hardness to stand up in service. The shrouds are flame hardened with a two-flame flexible-type tip, the torch being held stationary, and the work revolved. The hardening is carried well over the outer edge to prevent the rolling out of this edge in service, but is kept $1/4$ inch away from the ends of the gear teeth. Very high stresses occur at the gear teeth end, and the possibility of cracks or brittle material in this zone must be avoided.

JAW CLUTCHES

In previous illustrations, gears with integral jaw clutches were shown, the jaws of which were flame hardened. An excavator has a number of jaw clutches. Our machines have an average of about 10 such clutches, and most of them are flame hardened. Figure 10 shows a typical sliding jaw clutch. The former practice was to machine this piece, furnace harden, then grind the bore. The only reason that hardening was required was to prevent wear or crushing of the driving faces. The present practice is to machine complete, then flame harden the driving faces. The furnace-hardened clutches sometimes broke from hardening cracks. This does not occur in the flame-hardened parts, and they wear equally well.

Another type of jaw clutch used for locking one track while steering the machine is shown on Fig. 11. This piece was formerly furnace hardened, and, as it is a rather heavy piece, the hardening was costly. It is now flame hardened at a considerable saving in cost, and at no sacrifice in quality.

The method of flame hardening jaw clutches is shown in Fig. 12. Here a number of the pinions, shown previously in Fig. 7, are set up for hardening. It will be noted that a manual operation is employed. It would be possible to rig up a mechanical operation, but, as the surfaces to be hardened are short and absolute uniformity is not essential, a skilled operator will obtain satisfactory results and make better time than with a mechanical set-up, unless this set-up be sufficiently elaborate to be practically automatic. In the manual operation a two-flame tip is used with a separate water-quench attachment. The hardness is carried well over the corner to provide support for the driving face, but is kept back from the body of the clutch at the root of the jaw.

CONE ROLLERS

The cone rollers in an excavator are the cone-shaped rollers which support the rotating upper deck. They are subjected to heavy loads when rolling and much greater impact loads while stationary. During the digging operation all of the vertical digging forces must pass through these rollers. Ordinary material will not withstand this service. These parts can be furnace hardened, but since they have a considerable mass, a high surface hardness is not readily obtained. It would also be necessary to grind the bore after such hardening. Flame hardening of the rolling surface has proved satisfactory, and we believe the higher surface hardness realized by flame hardening is beneficial. The grinding of the bore is, of course, unnecessary with this method of hardening. Figure 13 shows one of these rollers and Fig. 14 the method of flame hardening. These rollers, ranging in diameter from 8 to 12 inches are mounted on cone centers, and rotated at a peripheral speed of $5^1/_2$ inches per minute, the torch being stationary The torch consists of a 4-inch wide, water-cooled, block-type tip having 33 flame holes and is mounted on an adjustable torch holder. In order to prevent a zone of unhardened metal directly across the face of the roller at the finish, the torch is set at an angle to the roller's axis. By this arrangement the soft line is helical and only a small portion of the contact line is not hardened. It would be possible, by means of shields, to reduce the width of the unhardened line, but this has not been found necessary, and the results secured with the present method have been satisfactory.

ROLLER PATH

The roller path, or rollway for the cone rollers, must, of course, be of a hardness suitable to carry the heavy roller loads. This roller path is a steel casting which is attached to the under frame and carries either integral or as a separately attached piece the ring gear by which the machine is rotated. Figure 15 shows one of these castings being hardened on the roller path. It can be readily appreciated that it would be extremely difficult to secure the desired results by any means other than flame hardening. This casting is 96 inches in diameter, and the roller path is 75 inches in diameter, with a $4^1/_4$-inch face. This particular roller path has an internal gear ring bolted to it at the holes shown in the outer flange.

For the hardening operation the finished casting is leveled on the floor, and a circular disk placed inside the roller path to provide a center and a surface on which a portable machine travels. An adjustable radius rod attached to the machine controls its travel to the proper circle. The same 4-inch tip is used here as is used for the cone rollers and is set at an angle from the radial for

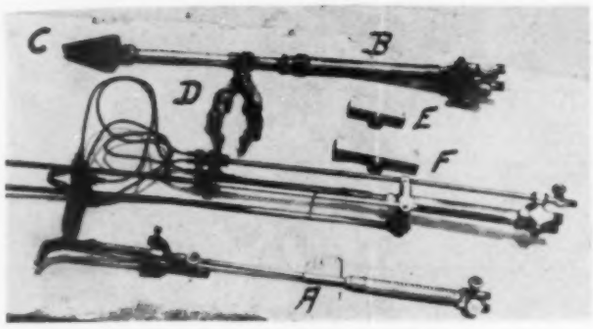


Fig. 20

the reasons previously given. In order to get a good depth of hardness the torch speed is held to 5 inches per minute.

WEAR BLOCKS

On the various sizes of excavators there is quite an assortment of wear blocks. These blocks are both drop forgings and steel castings. The majority of these blocks are used in the sleeve casting which guides the dipper stick, as it is racked in and out, to properly position the dipper for digging or dumping. The lubrication at this point is not the best, since there is no protection against the dirt and dust that is always present where excavators operate. Only extremely hard surfaces will withstand this wear, and for this reason the wear blocks are flame hardened. A number of these blocks are shown in Fig. 16. The largest is six by eight inches and is used with a rectangular dipper stick. The curved block is used with a tubular stick.

In hardening wear blocks a number of pieces are placed end to end on a rack, and the whole line flame hardened in one pass by a torch, mounted on a motor-driven machine running on a track. The hardening speed is 5 inches per minute. The tip is of the water-cooled block type, either curved or flat, as the work requires. The torch is also water cooled. This operation is shown in Fig. 17. Work of this nature may be handled very rapidly by this method. The tapped stud holes in these blocks sometimes require retapping after hardening. As it is impossible to retap in the hardened area, the operator follows the machine with a hand torch and, by heating the metal around the holes, draws the hardness back to a machinable range.

WIRE ROPE SHEAVES

The major functions of an excavating machine are performed by power transmitted by wire ropes or cables. A power shovel has a digging line of wire rope and frequently another actuates the dipper stick. A dragline excavator utilizes cable for both digging and hoisting lines. All other types of excavators have one or more operating lines of wire rope. The use of wire rope for power transmission necessitates the use of sheaves to change the direction of, or multiply, the forces. In many cases it is impossible to follow cable manufacturers' recommendations in regard to sheave diameters. Space limitations will not permit sheaves of the diameters which would produce the best results as regards wear. Wire rope being much harder than ordinary unhardened steel, the high unit pressures on, and the excessive bending of the rope about, small diameter sheaves, produce rapid wear in the throat of these sheaves. Also, when the rope is not guided, it may contact the sheave flanges and wear them away very rapidly, as in head sheaves of dragline or clamshell booms. As the wire rope wears, its diameter is of course reduced and, in turn, this reduced diameter wears the sheave throat to a corresponding radius of curvature. When a new rope is installed on such a worn sheave, it pinches, because the throat is of a smaller radius than the new rope, and the rope is very rapidly destroyed. To correct these conditions sheave throats are flame hardened. Where scrubbing on the throat flanges does not occur, only the tread is hardened. A tip, having a curved cross section, hardens the curved portion of the tread through an arc of about 45°. In this way a hardened surface in the pressure zone is provided. Where flange abrasion occurs, the entire throat, including the flanges, is hardened with a wedge-shaped tip, having its point rounded to conform to the shape of the throat.

A sheave-hardening operation is shown in Fig. 18. Here a sheave, mounted on cone centers and rotated to give a peripheral speed of 5 inches per minute, is being hardened. A special water-cooled tip and a water-cooled torch are mounted on an adjustable holder.

Figure 19 is that of a dragline fairlead and illustrates the application of flame hardening of parts used in connection with power transmission by wire rope. The horizontal sheaves guide the rope as it comes from the power drum and the sheaves mounted vertically in a swinging frame lead the rope from the horizontal sheaves to the dragline bucket. All of these sheaves are hardened. The curved guide castings on the front of the swinging frame are also flame hardened. The life of unhardened castings at this point is very short, while hardened castings resist wear successfully.

MATERIALS HARDENED

Most of the steels on which we do flame hardening fall in two classifications.

1. 1040 carbon steel, either cast, rolled or forged.
2. 0.35 carbon 1.00–1.25 manganese, 0.15–0.25 molybdenum.

The most of this steel is cast.

The hardness secured is usually within the range of 41 to 51 Rockwell C.

The depth to which hardening occurs is controlled according to the needs of the individual piece by varying the speed of travel, or the gas pressure, or both.

TORCHES

The torches used in the operations which have been shown may be classed under three headings.

1. Torches employing flexible type tips, neither torch nor tip being water cooled. Such tips are usually made from copper tubing with the tip either flattened or left round. With these torches the water quench is separate from the tip but may be attached to the torch.
2. Torches having a block-type tip, the tips only being water cooled. In this type the water passes through the tip to keep it cool and then out of the tip to serve as a quenching medium (see Fig. 20*A*).
3. In the case where tips are large or a great amount of heat occurs it is necessary to water cool both the tip and the torch. A torch of this kind is shown as *B*. Here again, block-type tips are used and the cooling water provides the quenching spray.

In Fig. 20 a number of other tips are shown. *C* is a special block-type tip for hardening sheave throats. *D* is the conventional adjustable tip, mounted on a universal yoke assembly, normally used for hardening gear teeth. *E* is a block-type tip used for hardening concave surfaces and *F* a similar tip for flat surfaces, such as flat wear blocks, cone rollers and roller path.

SPOT WELDING IN AIRCRAFT CONSTRUCTION*

By CHARLES F. MARSCHNER†

FROM the standpoint of airplane design and manufacturing the use of spot welding in aircraft construction divides itself into two fields; the welding of aluminum alloys and the alloys of steel. Aluminum alloys are generally used in preference to steel in both structural and non-structural parts for reasons peculiar to the aircraft industry. Because of the more widespread use of aluminum alloys the content of this paper will be limited to the spot welding of this material. For purposes of discussion the subject may be conveniently subdivided as follows: (1) Equipment, (2) operators, (3) design, and (4) shop procedures. Of these only the Equipment and Design phases will be covered.

With the adoption of the all-metal stressed-skin type of airplane design came the highly dependable but expensive riveted connections. From the beginning it became apparent that spot welding had very definite economic advantages over riveting in the assembly of sheet metal parts. This was, of course, the principle reason for the interest of aircraft manufacturers in the use of the process. Unfortunately first attempts to apply spot welding to aircraft were not very successful for several reasons. The process came to be regarded as a very delicate art requiring highly trained operators and complicated equipment to produce the high quality welds necessary where personal safety and the large capital investment represented by the airplane are so dependent on structural integrity. Reasons why the process was not an immediate success are numerous but among the more important were a lack of equipment suitable for aircraft spot welding, the fact that the more easily welded alclad materials were not then in general use, and a lack of experience in designing parts more suitable to the process. On top of this there was no true coordination of effort or standardization of welding within the aircraft industry with the result that each manufacturer who desired to use spot welding was forced to develop his own technique and methods. With the industry expanding by leaps and bounds and literally hundreds of projects requiring sizable expenditures for development work, few manufacturers were willing to allocate funds for spot welding development. The result is that most manufacturers have not yet adopted spot welding *except* for non-structural parts such as cowling, fairing, cabinets, etc. To the author's knowledge only one manufacturer has thus far produced any quantity of airplanes extensively utilizing spot welding on the basic structure for the armed forces of the United States. At least two others are now engaged in building airplanes with some of the primary structure spot welded.

EQUIPMENT

The technical features of spot welding equipment are presented elsewhere in this meeting but the particular equipment requirements of the aircraft industry can be dealt with here.

Whether alternating current operated welders or the more recently developed "stored energy" type are employed, certain features should be incorporated in the equipment to make it entirely suitable for aircraft work. Naturally, it must be reliable, capable of producing absolutely uniform, high quality welds at all times when properly set up and operated.

Extreme flexibility of the welder is highly desirable so that changes in the mechanical set-up, involving changing electrode holders and tips, gap between upper and lower arms, angle between the tips, etc., may be rapidly and easily made. Changes in electrical set-up involving heat, pressure and time should also be easy to accomplish. This flexibility is necessary for several reasons. The airplane is by nature a relatively large unit which must be made in quite a number of sub-assemblies for ease of assembly and repair. In addition the absolute necessity for saving weight results in a complication of the sub-assemblies which would not otherwise take place. This complication plus the use of many different gages, even in one sub-assembly, makes it necessary to use several set-ups on a considerable portion of the work. Obviously the combination of many parts and several set-ups per part makes it impractical to have a separate machine for each set-up even with airplanes being produced in the quantities now proposed for national defense. The equipment must be capable of being adjusted to take the parts more or less as they come; in small groups of identical assemblies.

Some equipment specialization is possible but never to the extent of having a machine to do one and only one job until that job ceases to exist and then dismantling and rebuilding it for a new job. For quantity production as applied in aircraft the best solution seems to be setting

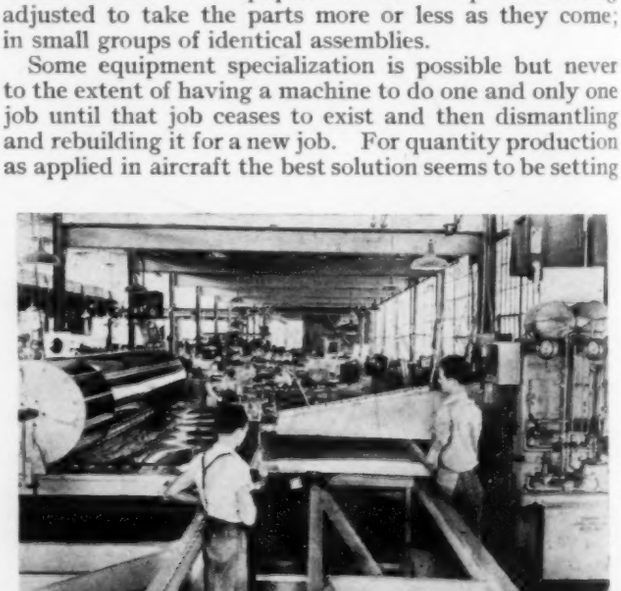


Fig. 1—Splicing Wing Skin for a Boeing Transport

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† McDonnell Aircraft Corporation.

up a battery of machines comprising two or three types or sizes, each capable of adjustment throughout a given range of mechanical and electrical set-ups. For experimental and test work at least one very flexible machine should be on hand.

In order to handle all parts which may be welded in the ordinary aircraft factory, the equipment on hand should be capable of welding all gage combinations between the range of two pieces of 0.016 inch up to two pieces of 0.125-inch stock. The heavier gages in this range cover structural parts which fortunately are usually relatively "flat." This makes it possible to maintain the gap of the welder arms in the position of maximum output thus avoiding excessive transformer sizes to cover conditions of extreme gap. With the present tendency toward heavier gages both of the gage limits in the above range might increase somewhat. In addition to covering this range of aluminum alloys some of the equipment should also have sufficiently low heat adjustment to permit the welding of stainless steel through the range of 0.010-inch to 0.064-inch stock for such parts as fire walls, shroud bridges, baffles, etc. which cannot be made from aluminum because of service conditions. Usually the lighter duty aluminum welders will accomplish this work.

The size of the welder varies with the type of work to be done. It has been found that a 36-inch throat, adjustable gap machine with swiveling electrode holders is very satisfactory for general usage. Where considerable welding is being done the equipment should be augmented by machines having smaller and larger throat depth to do more specialized work. An example of the use of a large machine is shown in Fig. 1 where wing skin for a Boeing transport is being spliced by welding.

The welder arms, both upper and lower, should be as small as possible without sacrificing rigidity, and the general mechanical design in the working area of the arms should be such as to permit bulky parts with internal welding to be slipped over either the upper or lower arms. While such welding is not normally encountered on well designed airplanes, there are occasions when it is necessary. In such instances the rocker arm type of welder has a definite advantage over the press welder.

It is desirable to have the electrode holders adjustable in the plane of the arms up to as much as 45° on either side of the vertical. Such adjustment is useful in welding restricted places which usually occur on parts constructed from relatively light gage material. The lower pressures used with the light gages somewhat simplifies the design of the adjustable electrode holders. A lower arm capable of being swung downward around its electrode as a center is also desirable for the welding of closed parts such as wing tip, leading edge and trailing edge assemblies.

In order that changes in electrical set-up may be easily made, as specified above, the controls for adjustment of the welding variables should be of the dial type, each being calibrated to give directly the output amperage, time and pressure as the case may be. Check controls to warn the operator that a sub-standard weld has been made are sometimes used but their effectiveness is dubious. A ballistic ammeter, graduated and calibrated to read actual welder output in amperes, should be sufficient as a check control for the operator since the heat is the most important welding variable. The other variables seem to be less likely to be incorrectly selected and even if they are the effect on weld strength is less noticeable.

The A. C. operated welders originally developed for aircraft work have proved very successful for both structural and non-structural welding. The settings for heat, time and pressure have been well established by experimentation and practice. However, it appears that the newer "stored energy" welders offer a number of advantages over the A. C. type. Important among these advantages are the elimination of heavy cables and special transformers to supply power to the welders, the decreased expense of relocating the welding equipment from time to time for improving plant layout, the use of two flat electrodes in place of rounded ones and the consequent time saving in cutting and dressing the tips, and the stronger, more uniform welds which are produced.

Several manufacturers are now using seam welders. While the application of seam welding can probably never be as general as spot welding due to the very nature of the welder design, it has a very definite place in aircraft manufacture. Seam welding may be used in the fabrication of skin-stringer combinations when these are built as separate panels to be applied to the ribs or frames, in fuel and oil tank seams, skin splices and the attachment of reinforcing strips and plates. Seam welders lack the flexibility to do all the varied types of work now being accomplished with spot welders.

No discussion of equipment could be complete without mentioning the desirability of having portable spot welding equipment made available to the industry. With the recent improvements in electrical cables, development of better insulating materials, development of stored energy control, and improved design of air operated mechanisms, it would seem that a practical portable tool could be built which could use the electrical circuit of a stationary welder for power. The relatively small gap and throat necessary in a portable welder should somewhat simplify the design despite the much higher output required for welding aluminum. Such a tool could not only be used for "tack" welding of parts before removing them from the assembly jig and thus avoid the use of clamps and screws, but could also be employed to do considerable welding while the parts remained in the jig. Portable welders would not necessarily be required to handle gages heavier than 0.045-inch stock.

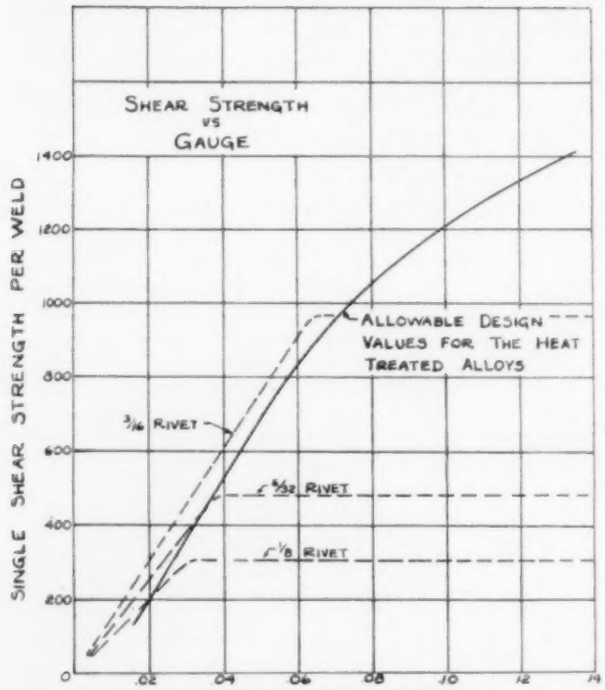
DESIGN

In designing parts for spot welding the first consideration is quality. No differentiation is made between structural and non-structural welding standards although non-structural parts do not require the high weld strength and uniformity so necessary on the primary structural assemblies.

In order that quality and uniformity of welds may be maintained at all times close coordination between factory and engineering is required. The welding variables of heat, time and pressure as well as electrode tip shape and cleanliness and the surface condition of the work all have an effect on weld strength and quality. This makes it necessary to set up welding standards in the shop which must be rigidly adhered to. Once the welding variables are fixed allowable design values for weld strength in shear and tension may be set, based upon a series of tests made under the standardized conditions of welding. With design values of weld strength available, structural analysis of joints is carried out just as it is in riveted assemblies.

Because the setting of each rivet in a riveted airplane structure represents an appreciable item of cost for the completed unit and because each rivet requires a hole which somewhat weakens the structure, riveted connections demand considerable attention from the structural analyst to insure that just the correct size and number of rivets are used in each joint. This is no small job in itself since there are usually more than 30 rivets for every

Fig. 2



NOTE: RIVETS ARE A17ST IN ALCLAD 24ST SHEET

pound of airplane structure and a large transport airplane may have a half million or more rivets. Welds are not nearly as expensive as rivets and do not require holes which weaken the structure. Because of this an excess of welds may be used and weld pitch standardized for the gage combinations employed. This results in some reduction in the drafting time required to design joints. It has the further advantage of increasing welding speed in the shop because the operator automatically knows what weld spacing to use when he checks the gage of the material. This avoids reference to blue prints as is sometimes necessary in the case of riveting. Usually

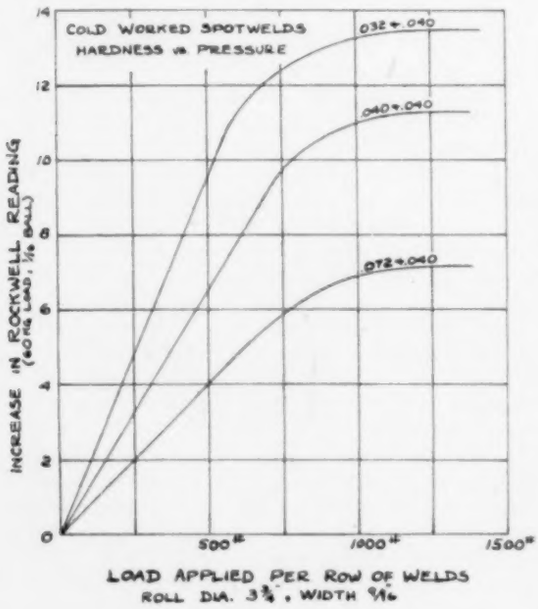


Fig. 3

two welds are used to replace every rivet although for any given gage the allowable weld strength will usually meet that obtainable with the most efficient size of rivet. Figure 2 gives typical allowable shear values for spot welds and rivets in 24ST alclad material.

In general it may be said that the ratio of the cost per rivet to the cost per weld is about 10 to 1. This ratio will hold relatively constant despite the complexity or simplicity of the design because both riveting and welding costs tend to increase as the complexity of the structure increases. The ratio is based on the assumption that about 5800 welds can be produced per machine every eight hour shift. Experience has shown that this rate can be maintained and even very appreciably increased if good design is employed and parts are scheduled so as to eliminate the many changes in machine set-up normally required in aircraft welding. This rate has been more than doubled in cases where large easily handled parts are welded in quantities. The cost ratio of 10 to 1 will not only depend somewhat on design and shop scheduling but also on the methods and basis used in computing riveting and welding costs.

Table 1 shows a comparison between riveting and spot welding on a typical spot-welded aluminum alloy airplane on which over 50% of the welding was on the basic structure. This includes such items as the highly loaded skin-stringer panels between the spars, flap and control surface torque boxes, and fuselage panels. The over-all ratio of welds used to rivets replaced is 2.16 to 1, a ratio which may be substantially reduced without danger particularly since the highest weld-rivet ratios actually occur on non-structural parts. With approximately two welds replacing every rivet and the cost of the weld one-tenth the cost per rivet the actual cost of fastening the separate parts together is about one-fifth as much for welding as for riveting. However this is not the whole story. In organizations where spot welding has been extensively and efficiently employed a number of very appreciable but uncalculable cost reduction have indirectly resulted. Since the very nature of the welding equipment requires that parts be brought to it for welding, assembly jigs are more quickly cleared and production thus accelerated. Parts are fitted and assembled in the jig and attached together with enough screws or patented fastening devices to prevent deformation due to handling and are then sent to the welders. In order to spot weld efficiently assemblies must be broken down into panels in so far as it is possible. The result of this has been a simplification of jigs and an accelerated trend toward stamped parts. The application of more advanced structural design has also resulted in an effort to provide simple, easily welded sub-assemblies. Some of these trends resulting from the use of spot welding have heretofore been overlooked.

On stressed skin structures where the sheet is subject to high stresses producing buckling this condition will often dictate the rivet pitch to prevent buckling in the immediate vicinity of the stiffeners. In such cases the closer weld spacings usually employed prevents buckling at no increase in cost over the usual welding cost.

An increasingly more important feature and advantage of spot welding is the flush surface condition permitted by its use. As speeds exceed 300 miles an hour projecting rivet heads cannot be tolerated and even the cracks commonly found around the heads of dimpled and even machine countersunk rivets add up to produce an appreciable drag when the entire airplane surface is considered. Spot welding eliminates the cost of filling these indentations around the exterior rivet head.

Another advantage of spot welding lies in the weight

Table 1—Comparison Between Riveting and Spot Welding Based on a Typical Spot-Welded Aluminum Alloy Airplane

Group	Actual No. of Spot Welds	Est. No. of Rivets Replaced	Ratio of Welds/ Rivets	Est. Wt. Saved in Lb.	Welds Req'd. to Save 1 Lb.	Rivets Replaced to Save 1 Lb.
Cowl	2,385	833	2.85	.374	6360	2220
Wing						
Complete	30,790	15,096	2.05	6.439	4800	2345
Leading edge	4,665	1,628	2.85	.812	5750	2000
Interbeam panels	15,950	9,136	1.69	4.568	3500	2000
Flap and aileron	1,890	840	2.24	.318	5950	2640
Tail surfaces	3,025	1,505	2.01	.374	8100	4030
Fuselage						
Complete	9,911	3,941	2.52	1.773	5580	2220
Panels	4,870	1,948	2.50	.975	5000	2000
Fairing assemblies	3,180	1,130	2.82	.393	8100	2880
Miscellaneous	2,555	1,030	2.48	.318	8050	3240
Complete Airplane	48,666	22,405	2.16	9.278	5240	2415

saving resulting from the elimination of rivet heads. Although the actual percentage of the total weight saved in this manner is small, usually representing about $2^1/_2\%$ of the structural weight, it may amount to several hundred pounds on very large airplanes when welding is extensively employed. Table 1 shows that on the average one pound is saved for every 2415 rivets replaced. This figure holds on the average airplane where the majority of the rivets are $^1/_8$ inch and $^5/_{32}$ inch diameter. Where larger rivets are used the weight savings will be increased.

Flange widths generally may be reduced where spot welds are used but good design practice usually dictates that the same flange width be used as for riveting. This is done because rivets are used at points where an extra thickness of material is picked up as at former intersections and gusset plates. These rivets, or the screws which are inserted in the rivet holes before the rivets are set, serve the additional purpose of holding the parts together until they are welded. As few rivets as possible are used however.

There is but one difference between structural and non-structural welding and that is that the welds must usually be cold worked where high compressive stresses, in the neighborhood of 40,000 psi, are applied parallel to a row of welds. Early tests on spot-welded compression panels indicated that permanent deformation of the weld material took place at stresses of about 22,000 psi with the result that buckling of the sheet between stiffeners became permanent at abnormally low stresses. Cold working the welds solved this problem. Because high compressive stresses are only applied along straight, flat panels, cold working of welds is not a difficult problem or an expensive one. Rolls are used for this purpose and pressures must be sufficiently high to be effective.

Figure 3 shows the increase found in the Rockwell hardness of spots before and after rolling. It may be noted that gage increases definitely decrease the difference in hardness before and after rolling but that the rolling pressure to produce maximum increase in hardness remains approximately constant for the gage combinations shown.

RECOMMENDATIONS

The following suggestions and recommendations are made with a view to advancing the art of spot welding and increasing the application of spot welding in the aircraft industry.

There is a definite need for standardization along some phases of aircraft spot welding and certain equipment to assist in this standardization must be developed. It is, therefore, recommended that the AMERICAN WELDING SOCIETY appoint a small group, representative of firms now engaged in the manufacture of aluminum spot welders, which group would be responsible for this standardization and development in cooperation with the aircraft industry and the Army and Navy. Overstandardization should naturally be avoided in the interest of continued development.

It is suggested that the following projects be considered part of the work of the group if this recommendation is acceptable.

1. The development of more suitable methods of calibrating and rating welders to the end that practically identical welding results may be obtained from any machine regardless of make.

It is suggested that ratings be based on peak output amperage with the welder arms in the most favorable position. For calibration a standard instrument or method of measuring actual output amperage throughout the range is desirable. It has been found that a pick-up coil slipped over the electrodes and attached to a ballistic ammeter can be used for calibration purposes.

2. The development of standards for amperage, pressure and timing as well as electrode tip diameters and shape for welding different gages of material.

These standards should be the best compromise between high weld strength, corrosion and vibration resistance, and practical production considerations. The standards should cover both the A. C. and "stored energy" type of welder. Once settings are standardized the mechanical properties are fixed.

3. The standardization of allowable design strengths for welds in shear and tension and the determination of fatigue limits, weld diameters and joint efficiencies.

This requires that consideration be given to methods of testing welds and includes the standardization of test specimens, data sheets for recording test data, etc. This must go hand in hand with the determination of optimum welding conditions.

4. The development of methods of inspecting welds and standards for checking out operators at regular periods just as they are now checked where torch welded tubular construction is used.

For inspection of welds a correlation between simple diameter and weld strength may be found suitable or, if check samples are inspected, a correlation between weld diameter and strength.

ELECTRO-BRAZING METHODS*

By R. J. WENSLEY†

THE joining of metal parts by brazing is an old and much-used art. As the name implies, brass was the material originally used and heat was supplied by charcoal fires. It was a good and useful method but now practically obsolete because of the development of new alloys to replace brass and faster, cleaner ways to heat the work. Alloys containing from 10 to 80% of silver are the most important of these materials. Another widely used alloy combines copper and phosphorus. Electrical heating methods are very popular. These include carbon-arc, electric-box furnace and resistance-heating methods. Since this paper describes the actual experiences in a specific plant only the latter will be discussed.

Electro brazing has been known and used for thirty or more years. Not until the past decade have its evident advantages become widely appreciated. Two closely related methods are used depending on the character of the work. The heat is generated by the passage of current of the order of thousands of amperes through the work and through blocks of resistance material immediately adjacent. In some cases the heat is developed by the resistance of the work itself. In other cases the heat is developed by the blocks of resistance material. The latter is the more usual method in our plant.

This paper is limited to the actual methods used and the results obtained by electro brazing in the manufacture of electrical switchgear by our company. No attempt is made to discuss the theoretical aspect of brazing materials and fluxes as these are adequately covered in papers such as one given by R. H. Leach before the A. S. T. M. in 1930 and another by Reed and Edelson before this society in February 1938.

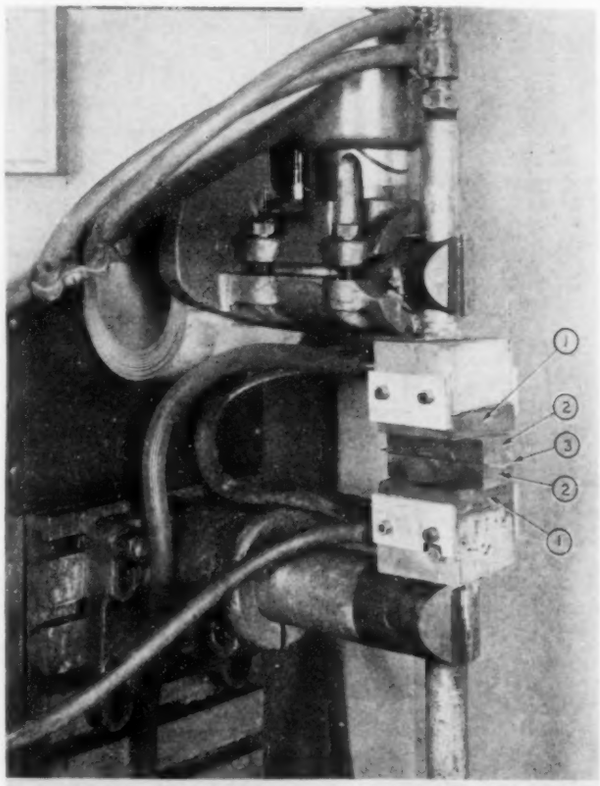
Five years ago the few brazing operations in our plant were done with gas or acetylene torches. At that time an experimental equipment was improvised from a 25-kva. testing transformer having a 5-volt secondary and a small arbor press. This gave us about 4000 amperes and enabled us to do quite a variety of work. Carbon blocks from our own stock of arcing tips were used as heaters. The results were so gratifying that the process soon became a part of our standard manufacturing procedure. The experimental equipment is still in use every day. Since that time we have purchased six additional units with the following kva. ratings; one 25, three 50, one 75 and one 150.

The availability of this equipment soon had its effect on the design of our product. Many joints in non-ferrous metals previously riveted or bolted and soft soldered were redesigned for electro brazing. Other designs were simplified and many pieces were built up with considerable saving in material and machining time. Some parts were designed that could not have been made by the older methods in use prior to the introduction of the electric process.

The limitations of our power supply have restricted us to methods suitable to relatively small machines. Some

Fig. 1—Typical Setup for Electro-Brazing

1. Carbon heater blocks
2. Copper parts to be joined
3. Brazing alloy



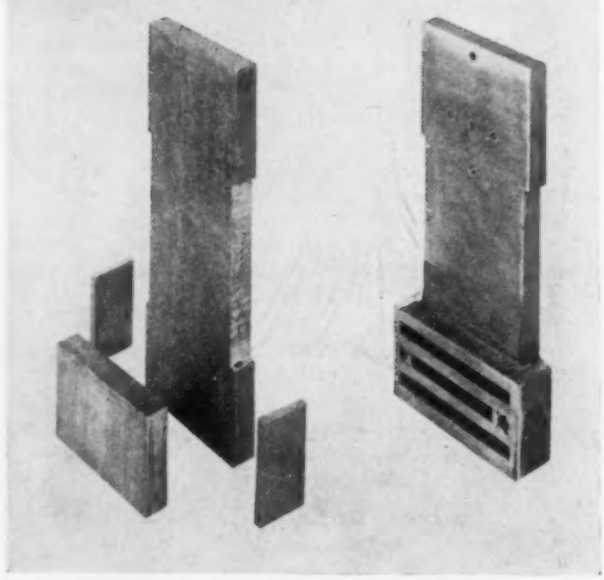


Fig. 2—Lower Terminal of 1200 Amp. Circuit Breaker

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Assistant General Manager, I. T. E. Circuit Breaker Co., Philadelphia, Pa.

work in the quick solidification of copper parts by the use of very high currents has been done by others. The machines used for this purpose require upward of a thousand kva. each which renders them unsuited for our power supply

A typical set-up for electro brazing as practiced in our plant is shown in Fig. 1. Hard carbon blocks are attached to the upper and lower electrodes of the press welder. Between the carbons are the pieces of copper to be joined. In the joint is a sheet of 0.003-inch brazing alloy. A thin coating of flux is added just before the parts are placed in this position. Pressure is applied by the air cylinder of the welder and then current is applied. The carbon blocks quickly become red and the heat is transferred to the copper parts. These rise in temperature very rapidly. The flux is seen to melt and shortly thereafter the brazing alloy melts. As soon as the liquidity of the alloy permits the parts to squeeze together forcing out some of the brazing material, the current is cut off but the pressure continued until the joint has set. If the flux is applied too soon, the liquid will evaporate and the dry flux will insulate the joint so that no current will flow and no heat will be generated.

Preparation of the work is important. Much of our work consists of butt joints. If the parts are rough, milling or shaping of the joint surfaces is necessary. The surface of drawn or extruded bars is usually flat enough to make a good joint. No scale or grease should be allowed in the joint. Parts which have been machined with any form of cutting compound or coolant are degreased in a hot trichlorethylene bath before brazing.

While much of our work is copper, we also braze various bronzes, brasses and steels as well as special contact materials. Our most difficult problems among the metals are aluminum bronze and lead brass. Both form insoluble oxides which the regular flux will not remove. These materials can be wetted with the brazing alloy by the mechanical removal of such oxides while hot and in the presence of the brazing alloy. A successful method is described later in connection with silver-molybdenum contact material.

Experiments have been conducted with a number of materials for use as heaters. For general use we find hard carbon blocks best suited, being relatively cheap and easily cut to fit the work. We purchase the carbon in blocks 3 x 6 x $^3/_4$ inch which is the size that just covers the flat electrodes of the press welders. For production runs involving assembly fixtures the carbon is not sufficiently durable as the surface burns away, thus changing the relative location of the parts. In such cases we use metallic molybdenum buttons press fitted into the assembly fixtures at the points where heat is desired. The body of such fixtures must be of copper in order to carry the heating current. Metallic tungsten has been tried but it oxidizes rapidly at the temperatures reached in brazing. We have used some stainless steel but so far with indifferent success. Materials such as nichrome and chromel are to be tried as soon as time is available. Certain alloys of tungsten, copper and other metals offered by manufacturers of spot-welding tips have been tried without success. These alloys crack and disintegration occurs much sooner than when molybdenum is used.

All of our work has been done with three materials, Easy-Flo, Sil-Fos and Phos-Copper.[1] The first two are the proprietary names of low-melting silver alloys, while the latter, as its name implies, is an alloy of copper and phosphorus. The working temperatures (not melting points) are, respectively, 1200°, 1325° and 1500° F. In many operations use is made of the differences in melting points to enable two or more successive joints to be made on the same assembly. These alloys are obtainable in sheets of various thicknesses, in sticks and in powder form. We use much of the silver in the 0.003 inch thickness. The copper alloy is difficult to roll and we are sometimes not able to get it as thin as 0.005 inch. One supplier of powdered alloy *C* provides a can somewhat like an oil can with a long spout to place the powder in position. Powdered silver alloys are available but we have not used them as yet.

Alloy *C* is used only where the joint surfaces are relatively large. For brazing studs into blocks or in structures where the mechanical stress is high we prefer to use the silver alloys. They are less brittle than alloy *C*. Neither of the alloys containing phosphorus should be used to join ferrous metals.

A good example of the use of two alloys having different melting points is shown in Fig. 2. This is part of the lower terminal of an air-circuit breaker. Above are the

[1] For the sake of convenience these alloys will hereinafter be called *A*, *B* and *C*, respectively. The "flow" temperature of the first two are 1175° F. and 1300° F. respectively.

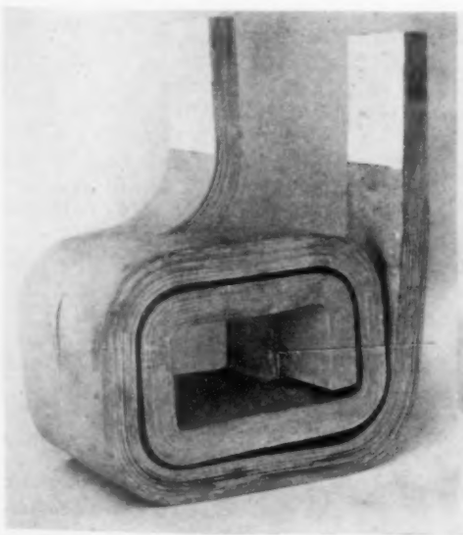


Fig. 3—Blowout Coil for High Speed Breaker Arrow points to joint at center of coil

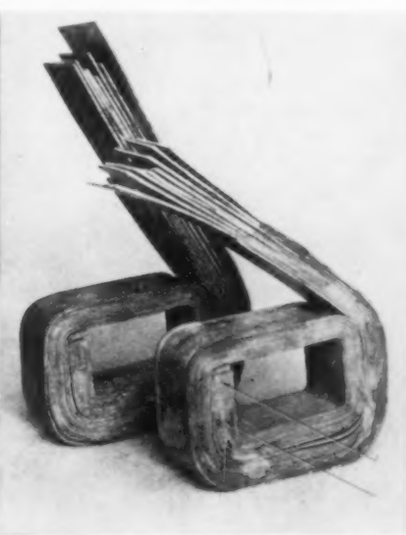


Fig. 4—Two Half Coils for High Speed Breaker Arrows point to area where ends of bars are brazed before coils are wound

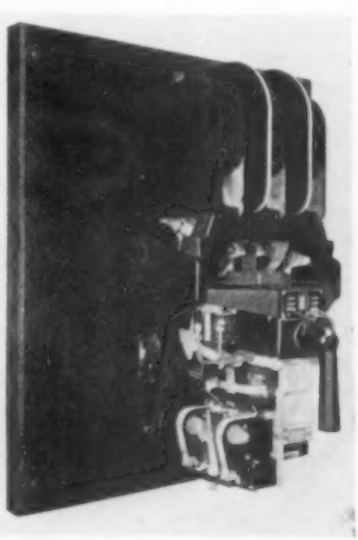


Fig. 5—Electro-Brazing Is Used at 45 Points in This 600-Amp. Type KB Circuit Breaker

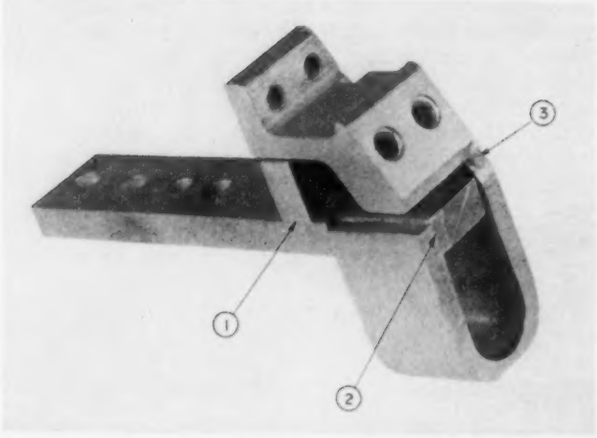


Fig. 6—Lower Terminal and Overload Coil of Type KB Circuit Breaker
The numbers indicate the joints and the order in which they are made

component parts, all of copper. The two largest pieces are first joined with alloy *C* using about 40 kva. for 50 seconds. Next the three $^1/_4$-inch slots are milled entirely through the smaller block. Analysis of the operation showed that it cost less to braze the one block and then mill the slots than to locate and braze four small pieces of copper to form the slots. Next the two small end plates are brazed with alloy *B* and at the same time two inserts are placed in the center slot. Twenty-five kva. for 40 seconds does this operation. The mounting bolt holes are then drilled and tapped after which the part is cleaned and polished. It is difficult to find the joints in this assembly. This piece was formerly made from a solid bar of copper, nearly an inch thick with a large part milled away. This was a costly machining operation and there was a large waste of copper. It is needless to say that the use of electro brazing in this instance saved a considerable amount of money.

One of the first important jobs which demonstrated to us the value of this process was the fabrication of a considerable number of large copper blowout coils for high-speed circuit breakers. As first designed these breakers were built with very intricate cast-copper blowout coils. The first cost was high and much hand labor was required to finish them. The electrical resistance of the cast material was high, thus increasing the full-load operating temperature of the breaker. The coil as designed for fabrication of bar copper is shown in Fig. 3. This complete coil is made of two wound coils as shown in Fig. 4. Eight pieces of $^1/_8$ x 3-inch copper bar are used for each half coil. One end is brazed with alloy *C* before each coil is wound. The inner ends of the two half coils are then brazed with alloy *A*. The carbon blocks are placed on the edges of the inner ends so that the heat must travel edgewise through the portion of the coil previously brazed with the higher melting-point alloy. About 75 kva. for ten minutes supplied the necessary heat. No weakening of the alloy *C* joints was noticeable after the second brazing operation.

Each joint is tested by passing 1000 amperes d.c. through the coil and measuring the millivolt drop across the actual joint. Those above an average value are reheated to a slightly higher temperature after which the drop almost always comes down to a permissible value. The finished coil weighs about 110 pounds. After three years of heavy industrial service no failures have developed in any of these coils.

We have recently placed on the market a new circuit breaker shown in Fig. 5. Very stringent requirements for compactness, ruggedness and high interrupting ability were laid down by the management when this breaker was designed. The engineering department made extensive use of electro-brazed parts to produce the finished device. In this breaker there are 45 separate joints made by electro-brazing methods. As an example, Fig. 6 shows a lower terminal and overload trip coil completely joined by this method. The T-piece attached to the long bar is first brazed with alloy *B*. Then the single turn coil is added with alloy *A*. Finally the upper member, an extrusion, is joined to the other end of the coil with alloy *A*. The assembly is then cleaned by acid dipping and cadmium plated. Elsewhere in the breaker the silver and alloy contacts are brazed to their supports, the flexible connectors are electro soldered, the blowout coils and upper terminals are brazed. In each case we believe the job is done better and for less money than by any other process with which we are familiar.

In our thermal-type circuit breakers of 100 amperes' capacity and below we make extensive use of contacts composed of powdered silver and graphite pressed into solid blocks. At one time these were made with a rivet molded as part of the contact. After riveting, soft solder was used to insure good electrical characteristics. We now braze the contact directly to its copper support. The contact is less expensive, the difficult riveting operation is omitted and the brazing operation costs less than the previous soft soldering. The production of these breakers is large, therefore the saving is well worth while.

Figure 7 shows a motor-driven press welder set up to braze silver graphite contacts to the upper line terminals for 100 ampere breakers. Mounted on the lower electrode is a simple assembly fixture to locate the contact. Directly below the location of the contact is a molybdenum button to supply the heat. To the right is a reel of alloy *A* ribbon 0.003 inch thick. In the center is a container for flux. A very thin aqueous solution of a proprietary fluoride flux is used. The copper terminal is first inserted. The ribbon is dipped in the flux and laid on the copper. The locating gate is swung over and the silver graphite contact dropped in place. This welder is motor driven, cam operated. It has a special friction transmission with infinitely variable speeds. The current is controlled by an ignitron contactor with the ignition circuit energized by a cam switch on the main operating cam shaft. To vary the time of current application the speed is adjusted. This operation is critical with respect to time. The heat is fed from the molybdenum button through the copper while a water-cooled copper electrode rests on the silver graphite. Just enough heat is allowed to reach the inner face of the contact block to enable the alloy *A* to wet the surface. Any considerable excess will cause disintegration of the silver graphite block while a slight deficiency will make a weak joint. The test for either condition is performed with a fixture having a square hole just the size of the contact block. The contact is placed in the hole and a definite torsional force placed on the end of the copper terminal. If deficient in heat, the contact will separate from the copper while if excessive the contact will fracture leaving a portion attached to the copper. For a contact $^1/_2$ inch square about 5 kva. for one second will give good results.

In our larger breakers we make use of a non-sticking contact material composed of molybdenum and silver powders briquetted to the proper shape. The oxide of molybdenum is not readily reducible by flux. It is therefore quite difficult to wet the surface of this type of contact. Mechanical abrasion seems to be the only practical method for coating the surface of such a contact with brazing alloy. Figure 8 shows how we wet the back of a

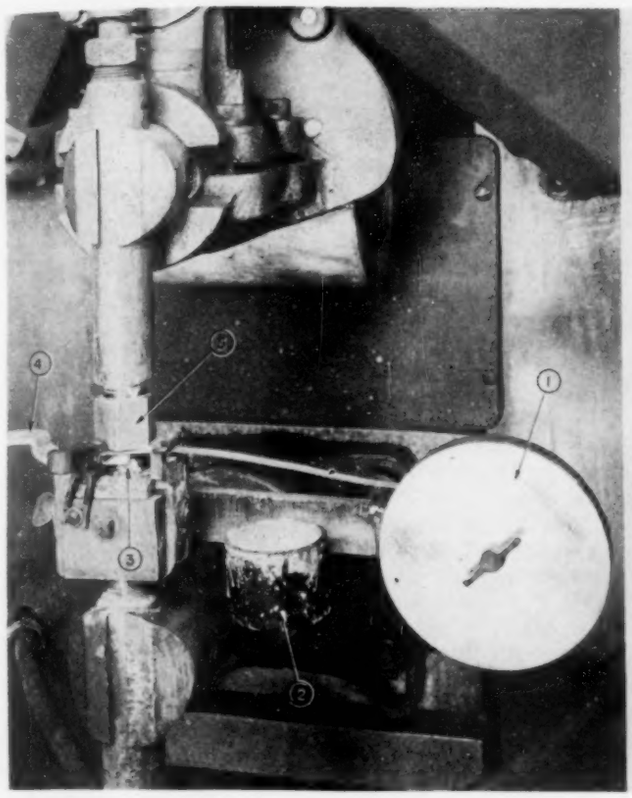


Fig. 7—Setup for Brazing Silver Graphite Contacts

1. Reel of Easy-Flo ribbon
2. Flux container
3. Molybdenum button
4. Line terminal of 100 amp. thermal circuit breaker
5. Water cooled upper electrode

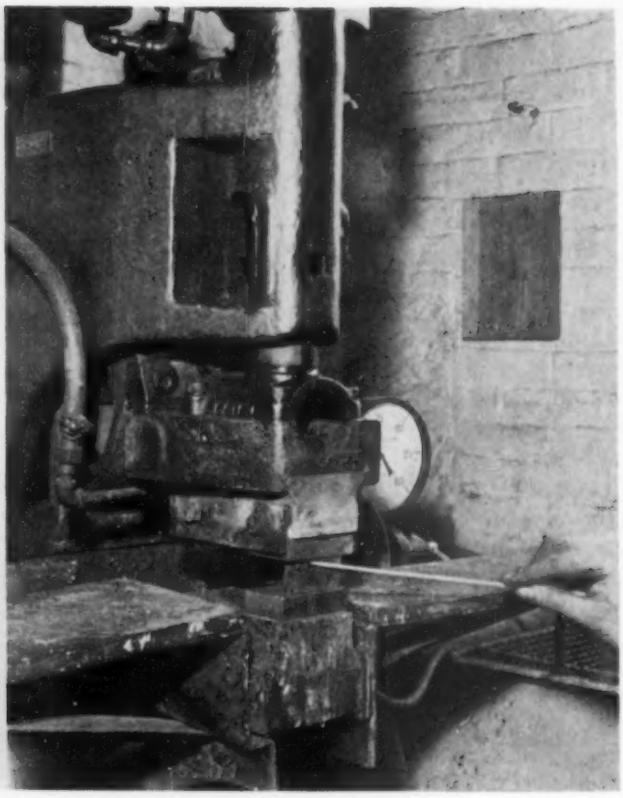


Fig. 8—Wetting Back of Molybdenum Silver Contact with Brazing Alloy

molybdenum silver contact with alloy *A*. The contact is placed on edge between the carbon blocks of an air-operated press welder. Current is applied to raise the temperature of the contact to the melting point of the brazing alloy. The stick of alloy is rubbed vigorously over the surface until the oxide is removed and the surface is wetted with the material. Enough remains to make the actual joint without the addition of sheet material. The contact after this preparation is placed on its supporting part with a light coating of flux and a carbon heater under the copper. It is best to send all the heat through the copper to avoid overheating the contact material.

In applying contacts to large blocks of copper it is often inadvisable to apply the heating blocks to the face of pure silver contacts. The silver may be melted before the copper reaches brazing temperature. It is often advisable to use two heater blocks applied to the large copper block in such manner as to leave the place for the contact piece exposed. The heat is applied and when the surface has reached the brazing temperature it is wetted by mechanical friction. The contact is laid in position and pressed down with a suitable tool. The heat is cut off and the pressure is maintained until the joint has set. If difficulty is experienced in securing a good joint the contact block is placed in position and slid to and fro under considerable pressure until the surfaces are well wetted. This will invariably make a good joint.

To prove the quality of the joint the test department passes a heavy d.c. current through the piece and measures the millivolt drop between two center punch marks placed close to either side of the joint. Sharp-pointed terminals are used on the ends of the millivoltmeter leads. An average is established for that particular type of joint and all that exceed the average are returned to be rebrazed. Sometimes it is enough to reheat to a higher temperature but if not, the joint is melted apart and the parts cleaned and reassembled. Examination of joints rejected by this test show a high percentage of the surface of one or the other piece not wetted.

The designing engineers have found it possible to use structures that would be impractical if made by other methods. A difficult assembly is the blowout coil shown in Fig. 9. It is a part of an anode breaker for use with a mercury arc rectifier. In spite of limited space this coil must have a high continuous carrying capacity and good mechanical strength. A set of parts is shown before brazing. A fixture is used to locate the parts as the completed assembly must be quite accurate. Three operations are required to build up the coil. Carbon blocks are used for heaters.

Soft soldering is done effectively in these same machines. Somewhat less current is used and of course much lower temperatures but the result is a very fast and very clean job. For this work we use half-and-half solder powdered to 200 mesh and mixed with a standard liquid flux. This material can be brushed on like paint and flows very freely into the joint. The saving in time is large. Some operations are clocked in 25% of the time required when done with gas torches and stick solder. We are now in the midst of a program which will, to a large extent, eliminate the use of gas torches for soft soldering in production work. The gain is twofold, because much of the larger soft-soldering jobs are done on parts for air-circuit breakers which must afterward be given a high finish suitable for the front of a switchboard. The scale and generally messy condition of the torch-soldered work makes the proper finish difficult to obtain.

The relative cleanness of the electro-soldered joints saves a considerable amount of time in the finishing operation.

On reviewing the infinite variety of work being done in our plant by these methods it is difficult to believe that it has all come within less than five years. As is the case with many other new methods or new devices we now wonder how we could possibly operate if this process were suddenly made impossible.

The machines which we use for this process vary from the 25-kva. homemade machine previously mentioned to the latest type of air-operated press welder with ignitron contactor and intermittent electronic control. Our heavier work is done with air-operated press welders and plain contactors controlled from a foot switch. For these heavy jobs there is no advantage in electronic control and automatic timing. We have one 50-kva. unit which is used either as a spot welder or a brazing machine. It is the one previously mentioned as having the special transmission for wide speed control. When running at high speed it is a spot welder but with the speed reduced it becomes an effective brazing machine for light, quick work where automatic timing is advantageous.

The largest machine (150 kva.) is of the air-operated foot-controlled type with an ordinary contactor and no timing devices. The higher transformer capacity is needed because of the long time required to bring some of the large blocks of copper up to brazing temperature. There have been several occasions when we have loaded the 50 kva. machines to such an extent that steam blew out of the water-cooling coils and a large fan was needed to keep the transformer cool enough to finish the job.

These notes on our experiences are of course very brief.

Fig. 9—Blowout Coil for Type DB Anode Breaker
Arrows indicate location of brazed joints

If we listed all the trials and tribulations incident to the use of this process, the book would be longer than some of the recent best sellers. In spite of our experience we cannot lay down any basic laws for the processing of any given part. Knowing the principles, it is a matter of experimentation to secure the best results. Machine operators should be selected from those capable of independent thought as much of the technique must be developed as the various problems arise.

We are convinced that there are more places in our plant where electro-brazing methods can be used to lower costs or improve quality. We expect to add several more machines before saturation is reached.

CODES FOR WELDED Pressure Vessels*

By D. S. JACOBUS†

THIS paper bears on Codes for Fusion Welded Pressure Vessels in use in this country, reviews some features which are now pending and refers to developments that may be made in the future. It includes boiler drums as well as unfired pressure vessels.

Restrictive rules for what was then known as autogenous welding were published in the A. S. M. E. Boiler Code issued in 1918. These rules sanctioned the use of autogenous welding only where the stress or load was carried by other constructions which conformed with the requirements of the Code and where safety was not dependent upon the strength of the weld. A number of hearings were held by the Boiler Code Committee on the use of autogenous welding. Little progress was made and no agreement could be reached on more liberal rules than those contained in the Code.

Progress was made in welding through the extensive use of welded pressure vessels in services exempted from Boiler Code rules, particularly in the petroleum and chemical industries. In 1928 the Council of the A. S. M. E. approved a statement by the Boiler Code Committee that it would be justified in publishing rules which would be generally applicable even though they could be met only by a single manufacturer under some patented process, but that the Committee could not sanction the use of fusion-welded pressure vessels built by any particular manufacturer to the exclusion of others except through restrictions that might result from the application of a general rule in the Code. Up to that time there had been no active cooperation between the work of the Boiler Code Committee and the AMERICAN WELDING SOCIETY. The SOCIETY suggested that it cooperate with the Boiler Code Committee in the formulation of more liberal rules. The Boiler Code Committee gladly accepted this proposition and from that time on there has been full and complete cooperation between the two organizations.

The proposed specifications for fusion welding of drums or shells of power boilers were published in the March 1930 issue of *Mechanical Engineering* and shortly thereafter a complete revision of the fusion welding rules for unfired pressure vessels. In August 1930 on the basis of tests made at the Barberton plant of The Babcock & Wilcox Company, the Bureau of Engineering of the U. S. Navy Department issued specifications for fusion-welded drums. These specifications included the requirement that all main seams be X-rayed and a number of steam and water drums for boilers for marine service were constructed for the U. S. Navy. This was the turning point in what proved to be a rapid advance in the development and use of fusion welding.

* To be presented at Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.
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The rules stated that the responsibility for securing safe welding rested on the manufacturer, who was required to test the welding operators. This principle is still maintained. The rules were more restrictive in some particulars than they might have been, the main idea naturally being to secure safety. Later on simplifications were made as the rules were tried out in practice.

The principal Code for stationary boilers is the A. S. M. E. Boiler Code. Section VIII of the A. S. M. E. Boiler Code covers Unfired Pressure Vessels. The API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases was prepared for the use of the petroleum industry at a later date than Section VIII of the Boiler Code. The Bureau of Engineering of the U. S. Navy and the Bureau of Marine Inspection and Navigation have Codes. The Interstate Commerce Commission, the American Bureau of Shipping and Lloyd's Register of Shipping also have their own rules.

To the ordinary layman the so-called factor of safety appears to be the all-important element. There is no engineering term, however, that has led to a greater amount of misunderstanding. The factor of safety as ordinarily computed is based on some stress in the shell of the vessel which can be readily computed but in many cases there are supplementary and concentrated stresses which may lead to trouble if neglected. Such conditions make it necessary to consider other than the computed factor of safety in determining the safety of the vessel.

There has been some misunderstanding when differentiating between Section VIII of the A. S. M. E. Code and the API-ASME Code. To those who made only a casual examination of the Codes it seemed that the main difference was in the use of a factor of safety of 5 for unfired pressure vessels built under the Boiler Code and a factor of safety of 4 for those built under the API-ASME Code. This was far from correct as the main difference between the two Codes is that the Boiler Code covers the construction of new vessels and has no mandatory rules on when they shall be discontinued from service, whereas the API-ASME Code also covers the operation of the vessels and specifies when they shall be discontinued from service on account of deterioration.

The API-ASME Code contains a mandatory section on inspection which requires that the vessels be thrown out of service or the operating conditions be made less severe if the factor of safety would otherwise be lower than 4. This mandatory system of inspection was not considered by some of those who purchased unfired pressure vessels under the API-ASME Code for use in states that had not adopted the A. S. M. E. Unfired Pressure Vessel Code, which thus resulted in omitting the most important safety element of that Code.

There is a second important difference between Section VIII of the A. S. M. E. Boiler Code and the API-ASME Unfired Pressure Vessel Code which is that the API-ASME Code gives a single set of rules to cover the construction of vessels for petroleum liquids and gases, whereas Section VIII of the A. S. M. E. Boiler Code gives different rules for different classes of service. The rules of the A. S. M. E. Code in requiring different constructions and precautions in manufacture for different degrees of hazard are in line with the A. S. A. Code for Pressure Piping, American Tentative Standard, where the rules for gas and air piping for power, industrial and gas-manufacturing plants when installed within the boundaries of cities and villages are more exacting than those for cross-country transportation systems. They also are in line with the rules for welded pressure vessels of Lloyd's Register of Shipping, which follow in a general way those of the A. S. M. E. Code.

On account of the misunderstanding that resulted from the use of both Section VIII of the A. S. M. E. Boiler Code for unfired pressure vessels and the API-A. S. M. E. Code, a Special Committee of the Boiler Code Committee was appointed to study the two Codes and prepare a suggested revision of Section VIII of the A. S. M. E. Boiler Code which would consolidate the best features of the two Codes. The Special Committee has submitted a preliminary draft of a suggested revision to the Boiler Code Committee to be used as a basis for a more formal draft to be prepared for general discussion. It is hoped that an agreement will be reached on all features which are pending, and that it will be possible for all parties involved to agree on a single construction code.

The rules of the Bureau of Marine Inspection and Navigation, formerly known as the Bureau of Navigation and Steamboat Inspection, Amended Rules I and II, General Rules and Regulations, of January 1, 1935, which are still in use, contain a section on rules for fusion welding under the following note:

> "(These rules are based on those prepared by a subcommittee on welding in marine construction of the AMERICAN WELDING SOCIETY, which in turn were based on those prepared by the boiler code committee of the American Society of Mechanical Engineers with the cooperation of the AMERICAN WELDING SOCIETY.)"

The rules of the Bureau are under consideration for a general revision. A meeting of the A. W. S. Committee on Welding in Marine Construction was held last March and recommendations for a revision of the welding rules were forwarded by its Chairman to the Bureau of Marine Inspection and Navigation.

The circumstances which led to the note published at the head of the welding section of the General Rules and Regulations of the Bureau are of special interest to the AMERICAN WELDING SOCIETY.

The American Marine Standards Committee issued a set of rules in 1929 for the design and construction of marine boilers and pressure vessels. The Steamboat Inspection Service prepared a tentative set of rules of its own which it submitted to the Boiler Code Committee for comments and suggestions. The American Standards Committee, acting through the Society of Naval Architects and Marine Engineers, petitioned the Honorable L. P. Lamont, then Secretary of Commerce, to recognize its boiler rules as a standard. At the suggestion of Secretary Lamont a Committee, which was known as the Committee to Coordinate Marine Boiler Rules, was formed to coordinate the two sets of rules, each of which had been formulated by a department of the Government. The members of this Committee represented the Society of Naval Architects and Marine Engineers, the American Bureau of Shipping, the National Council of American Shipbuilders, the Bureau of Navigation and Steamboat Inspection, the American Society of Mechanical Engineers and the American Marine Standards Committee. It was at first proposed by the Committee to Coordinate Marine Boiler Rules to include no detailed rules for fusion welding. When the rules which were being prepared by the Committee were nearly completed it was decided to embody rules on welding. On December 19, 1931, a subcommittee started the work of preparing a set of fusion welding rules for marine use which were based on those of the A. S. M. E. Power Boiler Code. Through the cooperation of and a special action of the AMERICAN WELDING SOCIETY these rules were approved by its Board of Directors January 5, 1932. The speed at which these rules were prepared and approved in order to make it possible to publish

them in the Marine Boiler Rules shows what the Society can do in an emergency.

The A. W. S. has done much to standardize the rules for welding through the issuance of its rules for Qualification of Welding Processes and Welding Operators, which have met with general favor and have been embodied in the A. S. M. E. Boiler Code and other Codes.

The A. W. S. Rules for Fusion Welding Steam, Oil or Air Piping in Marine Construction, accepted by the Board of Directors as a standard in October 1938, have been used by a number of manufacturers and the Bureau of Marine Inspection and Navigation proposes to embody them in its General Rules and Regulations.

The Boiler Code Committee and its subcommittees have been active in extending the rules to cover alloy steels. A vast amount of time and effort has been expended in setting the working stresses at different temperatures for both ferrous and non-ferrous materials. In arriving at the working stresses the rate of creep at higher temperatures is considered, as well as other physical properties of the steel, such as the yield and ultimate strengths.

In the early days of the formulation of the A. S. M. E. Codes there was considerable discussion on whether the allowable working pressure should be based on the maximum stress, such as exists at the sides of an unreinforced tube hole where the stress is over twice the average stress in a ligament between two of the holes, or whether the custom then prevailing should be followed and the operating pressure based on the average stress in the ligaments. It was finally agreed to use the average stress in the ligaments and to provide for the use of steel or other material with a degree of ductility which would tend to equalize the stresses. It was pointed out at the time that should the maximum stress at any point in the drum obtained in applying the initial hydrostatic test be made the criterion for establishing the allowable working pressure, it would necessitate the use of lower stresses than those which had been found to be safe in long-time service. For example, in the case of staybolted constructions the Committee aimed to provide rules which would prevent the staybolted plates from ripping apart should two adjacent staybolts fail, as the Committee was told they sometimes do in locomotive practice. The fact that it was common practice to drill the outside ends of the staybolts with telltale holes of small diameter extending beyond the inside of the plates showed that one or more of the staybolts might be expected to fail. Should an endeavor have been made to design a staybolted structure by employing the elastic theory, much heavier plates would have been required than practice had shown to be safe. Finally a formula was adopted for staybolting which was made to fit existing practice.

A number of rules in the Boiler Code are based on existing practice. An example of such rules are those to limit the size of unreinforced openings that were based on data secured through the use of a great number of constructions which had given satisfaction in long-time service.

A great number of tests of fusion-welded vessels at intermittent pressures have been made with the idea that they show more nearly what may be expected in actual service than ordinary bursting tests.

All that has been said does not count against the value of the elastic theory in solving special problems, such as in the construction of the penstocks for Boulder Dam, where photoelastic investigations were made and tests of models constructed to one-sixth scale.

There are rules in the A. S. M. E. Unfired Pressure Vessel Code which limit the effect of stress raisers, such as the use of tapered connections for certain parts.

There is a special rule for seamless forged vessels which sanctions a factor of safety of 4 in place of 5 for certain grades of high-tensile-strength steels for low-temperature service. The rule prohibits the placing of holes in the thinner part of the shell which has a thickness corresponding to a factor of safety of 4. It contains a requirement that when a reinforced opening is placed in a shell it shall be made of a uniform thickness for its entire circumference where reinforced, the thickness being such that the calculated stress in the reinforced part before piercing for the opening is not more than one-half the maximum stress allowed for the thinner part of the shell. The end of the reinforced part is tapered to avoid stress concentration where it meets the thinner part of the shell.

Constructions to reduce stress concentration may be provided in welded drums which could not be employed in riveted constructions; for example, in a welded boiler drum having a thick tube sheet and a thinner wrapper sheet, the cross-sectional symmetry where the two plates join can be maintained as the center element on both the thin and thick plates can be made to come on the same circle, whereas this cannot be done in a riveted drum. A number of rules which were applicable to riveted drums, such as those for reinforcement, have been embodied in the Code for welded drums and are not as good as they might be for welded drums. Eventually the reinforcements best adapted to welded drums may be specified, with the privilege of using higher allowable working stresses than for the older form of reinforcements.

The question of stress due to a lack of circularity has been given much attention. No rules for computing the stresses due to out-of-roundness are given in either the A. S. M. E. Boiler Code or the API-ASME Code, whereas a limit is placed on the amount that the drums may be out-of-round. The stress due to the out-of-roundness of the drums as measured by the maximum allowable difference in two diameters is usually considerably less than that produced by the conjunction between thick and thin plates where a wrapper sheet is joined to the tube sheet and the inner face of the sheets made circular. This construction is one that has been employed for a long time where the joints are riveted and the stresses are such as to allow it to be used with safety. This should not stand in the way of the adoption of a more exact rule where the center lines of the thicker and thinner parts of the drum sheets can be made to come on the same circle and the use of higher allowable stresses for the more exact rules. Constructions to avoid stress concentrations, such as making the center line come on the same circle and the use of tapered reinforcements and connections, are particularly advantageous where high-tensile-strength steels are employed which have a high yield strength.

Both the yield strength and the ultimate strength of the material used in the construction of boilers and superheaters are considered in establishing the allowable working stresses given in the Boiler Code. The general basis used in the Code is to limit the allowable working stress for the lower temperatures for steel plates to a constant figure based on one-fifth of the ultimate strength up to the temperatures where the yield strength or the rate of creep are the governing factors. For the higher temperatures the allowable working stress at a given temperature is set at a figure not to exceed one-half the yield strength nor 80 per cent of the stress required to produce a rate of creep of 1 per cent in 100,000 hours. Those working on the subject were forced to make a study of a large amount of data on creep, some of which was conflicting, and had to use considerable judgment in deciding on the best figure to use. In some cases con-

sideration was given to results which had been proved in service to be satisfactory.

The Code rules which were developed for riveted construction were modified to cover drums and shells fabricated by fusion welding. The advantage of avoiding stress concentrations in welded drums and shells has been kept in mind, whereas in most cases no higher allowances were made for fusion-welded vessels where the stress concentrations were reduced than are sanctioned for vessels of riveted construction. It must be borne in mind that fusion welding is a comparatively new art and that it is better to proceed in a cautious way rather than to advance too rapidly, and this has been a factor in allowing no higher working pressures in welded vessels.

More and more attention will undoubtedly be paid to designing fusion-welded vessels so as to use the material from which they are constructed in the most economical way. As already stated, the Boiler Code Committee has specified tapered reinforcements and other means of reducing the effect of stress raisers for certain special constructions and allowed higher working pressures for such constructions than where there are stress raisers. There is a broad field open for improvements which, if properly carried out, should result in the use of higher allowable working stresses than at present. Before sanctioning the use of higher working stresses, however, the possibility of corrosion fatigue and of the so-called aging of the steel must be considered. More and more data are being secured on the use of special alloy steels and their behavior under different working conditions, and in view of their increased cost a reduction in weight would be especially advantageous. There is a vast field to consider in making advances, and due caution must be taken to avoid unforeseen difficulties.

An ideal design would be to proportion the tube holes and any other unreinforced openings so as to meet conditions which have been found to be safe through long-established practice and through intermittent pressure tests, and to employ 2-inch strain gages in determining stresses in individual localities in the way that was done at Boulder Dam. One of the results of applying this method would be that many of the abrupt section changes that are now allowed would not be permissible, but the structures as a whole could be made to weigh less and cost less and be as safe as they are today. The field is still open for advancement and important improvements are bound to be developed.

The designation "Boiler Code Committee" is an abbreviation of the title given the Committee by the Council of the A. S. M. E. when it was established, the full title being "Committee to Formulate Standard Specifications for the Construction of Steam Boilers and other Pressure Vessels and for Their Care in Service."

There are now 22 members of the Main Committee and 8 honorary members. Each state and municipality that accepts the Code is invited to appoint a representative to act on a Conference Committee, which now includes 40 members. There are now over 150 men in all who are members of the Boiler Code Committee, its subcommittees and special committees and the Conference Committee.

When the Boiler Code Committee was first formed its members were listed as representing certain groups in the industry. Later on this practice was discontinued and it was stipulated that the members should act in their individual capacity entirely apart from any commercial interest. This practice is now zealously guarded by the Boiler Code Committee.

The National Board of Boiler and Pressure Vessel Inspectors is composed of Chief Inspectors of the states and municipalities that have adopted the Code. This Board since its organization in 1921 has functioned to secure uniformity in the administration and enforcement of the rules of the Boiler Code. Its cooperation with the Boiler Code Committee has been extremely helpful. Inquiries received which bear on the administration or application of the rules are often referred directly to the National Board. Where an inquiry is not clearly an interpretation of the rules nor a problem of application or administration it may be considered by both the Boiler Code Committee and the National Board.

The American Uniform Boiler-Law Society cooperates in obtaining uniformity in the use of the Code. This Society has been instrumental in aiding legislation by drawing up bills bearing on the adoption and enforcement of the Code.

All final actions of the Boiler Code Committee have been unanimous. This does not apply to votes taken at the meetings, but to letter ballots which follow. A single adverse letter ballot up to date by a member of the Boiler Code Committee or of the Conference Committee has resulted in holding up the matter until it can be reconsidered by the Boiler Code Committee and in all cases the final actions have been unanimous. It can be appreciated that with a Committee as large as the Boiler Code Committee there must be a full understanding and willingness between the different members to cooperate in order to make such a unanimous procedure possible.

DISCUSSION BY C. H. GAY†

One factor which occurs to me, in reading Dr. Jacobus' paper for presentation before the AMERICAN WELDING SOCIETY, is the effect hydrostatic pressure testing has had on the satisfactory operation of boiler drums as designed to present Code requirements.

Reference is made in Dr. Jacobus' paper to the possibility of using higher allowable working stresses than those now used, which presumably means reducing the present factor of safety.

As we all know, the knuckles of drum heads for the lower pressure ranges pass through the yield point under a hydrostatic test pressure of 200% of the working pressure. These drum heads, in general, perform satisfactorily for an indefinite period of time, even though the knuckle zone has been subjected to yield-point stresses. I believe there is a definite reason for this satisfactory operation which ties in very closely with the relation between the test pressure and the yield point of the material. As the test pressure is applied, the yield point of the material is exceeded and some plastic distortion occurs, as evidenced by the appearance of Luders lines and cracking of the scale. When the hydrostatic pressure is released, these zones which have been subjected to plastic deformation return to a state of equilibrium in which compression stresses are established in the zones which have plastically deformed. Due to this change in the stress distribution in the plate, stresses are maintained at values well below the endurance limit under the normal operating pressure.

This same reasoning will apply to any section of the drum even though the design of the drum is such that the 200% pressure test does not actually produce plastic deformation at any point in the drum.

Briefly, what I have in mind is that we might expect trouble on our present design of drum heads if they were not subjected to test pressure greater than the normal working pressure, and the opportunity of readjusting stresses, as outlined above, is eliminated.

† Assistant Superintendent, The Babcock & Wilcox Company.

WELDING ELECTRICAL EQUIPMENT*

By R. A. TAYLOR†

ELECTRIC arc welding has advanced the art of fabricating electrical equipment in that it provides the designer and manufacturer with a convenient and extremely flexible tool whereby numerous items may be combined to form an integral usable machine.

Arc-welded fabrication encourages the designer to modernize new equipment; to take advantage of low-cost structural shapes and low-alloy steels; to secure a completed machine with a pleasing contour, reduced weight and minimum cost yet not require an expensive or exorbitant installation of fabricating equipment by the manufacturer. To fabricate by arc welding the manufacturer is required to have suitable handling equipment; hoists, cranes and manipulators; pre-forming equipment; shears, presses, press brakes, punches, cutting machines, rolls; and welding equipment; machines and accessories. The amount of equipment required is dependent upon the quantity and magnitude of the equipment fabricated, yet this equipment will not at any time exceed the amount of capital investment which would be required for a foundry capable of producing the wide variety of sizes and shapes of electrical machinery similar to that manufactured by the arc-welding fabricator.

Furthermore, arc welding does not require extensive and expensive welding personnel training. A good welding operator may be trained in a relatively short time when compared to the training necessary to produce a first-class pattern maker and foundry operator. Usually trainees may be selected and given some instructions in the form of welding school preparation and then assigned to production jobs where they may be closely supervised for the first few months, while they are improving upon technique and training.

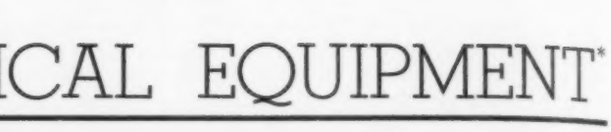

Fig. 1—A Wooden Model Facilitates Design and Manufacture

In the manufacture of electrical machinery, particularly of the large sizes which are manufactured to specific customer requirements, welding provides the foundation for economic manufacture. In short, there is seldom if ever more than one machine made of identical design because these large machines are always made for special application. Were castings required for all parts as in past years, pattern costs would be prohibitive. There would be a tendency toward a limited variety of designs. The welding application is a source which tends to increase the possibilities for more advanced and up-to-date design because practically anything can be fabricated with its use.

DESIGNING FOR WELDING APPLICATION

The advantages of using welding effectively can be considerably modified when the designs are not made

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

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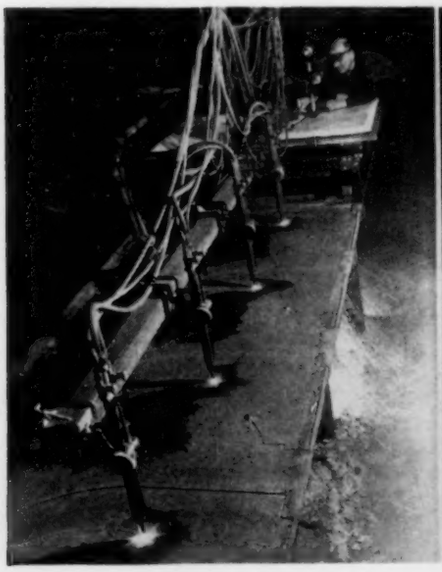


Fig. 2—Multiple Torch Burning of Plates Proves Economic

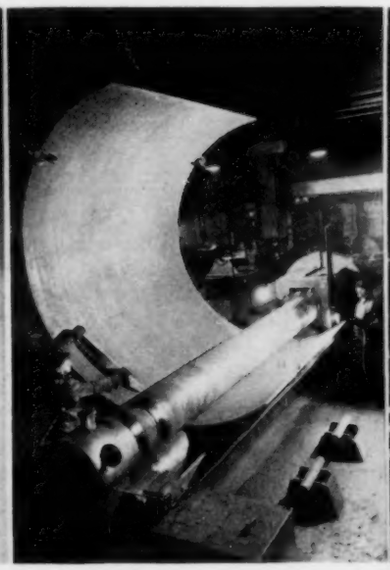


Fig. 3—Rolling to Correct Contour Eliminates Unnecessary "Fit-up" Time

Fig. 4—Assembling the Outer Shell to the Inner-Turbo Frame Structure

with the end in view of providing accessibility. The drawing board and the drafting room are the place to design for welding. Any improvement that can be suggested once a design is made and reaches the shop is acceptable, but we prefer, where possible, to plan our design so that they best suit our welding technique and fabricating facilities.

The first requirement of any welding structure is, of course, that it be strong enough to carry the load that is required of it. Most structures of this nature can be designed in such a way that the weldment carries no greater load than the parent metal it joins. After satisfying the engineer's strength requirements for loading and the shop requirements for accessibility, there are often other features which must be given consideration. Certain mechanical parts must be oil-tight, such as the chamber that carries the thrust-bearing assembly of vertical machines. Here again the design plays an important part in its selection of the proper type of double welding to provide adequate test facilities in determining oil-tightness or gas-tightness.

Since the flexibility of welding allows wide variation in design features, one can say designing for contour is established. No longer are fabricators particularly concerned by unusual shapes which are required by the engineering department as a function of the design for it is known that almost any shape desired may be made. However, it is sometimes necessary to exercise a dampening effect on the aspirations of the engineering department or the shop would be fabricating and welding difficult shapes and contours that are too expensive for practical purposes. Generally, the shop engineers and the design engineers work in very close cooperation so that designs may be made to suit the capacities that are available with existing auxiliary equipment. This is done in an effort to reduce unnecessary extra work which might be required and also to simplify unusual features and designs that might require expensive manufacturing procedures.

For some machines this coordination and cooperation is carried still further to the point of making very complete layouts of machines, sketches, and models of the type of equipment which is finally expected to be produced. Figure 1 shows such a streamlined model of a large steam-turbine-driven alternating current generator. The making of models has been found to be a very great aid to the

Fig. 5—Welding Manipulators Provide More Accessibility to the Welding Operator

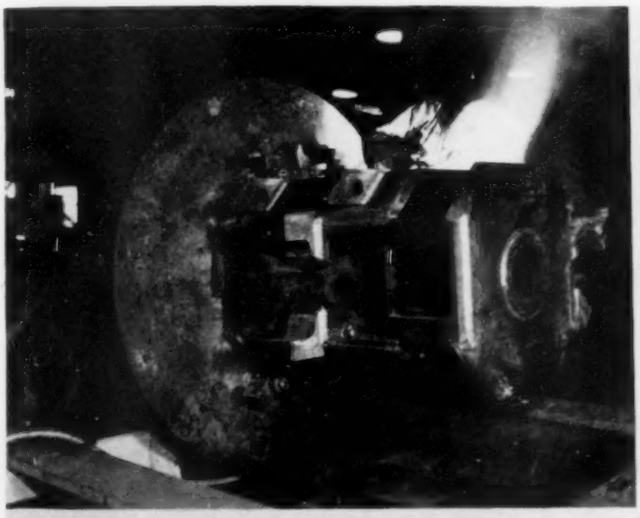


Fig. 6—Combination of the Manipulation Facilities and Automatic Welding Equipment Shortens Production Time

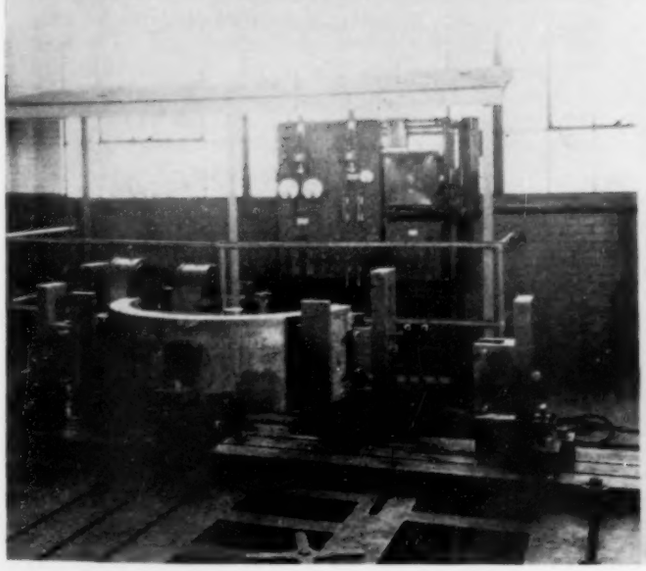


Fig. 7—Locating Facilities Provide the Accuracy Necessary to Successful Fabrication

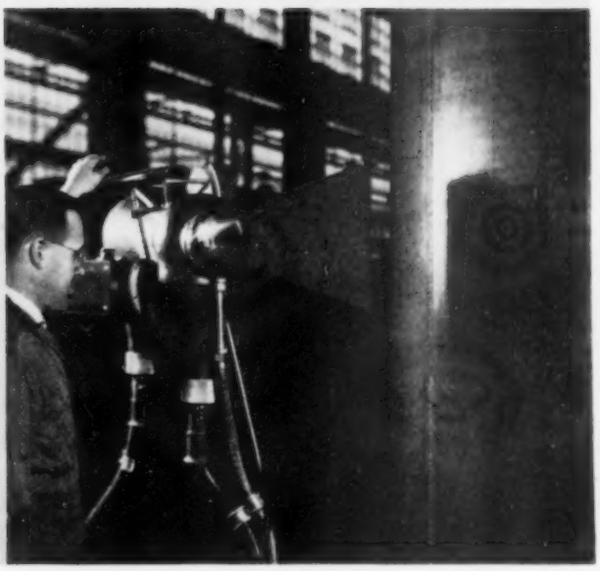


Fig. 8—Extra Examination of Welds for Pressure Vessels Proves Its Usefulness

Fig. 9—Modern Electrical Equipment Can Be Fabricated to Streamline Contour

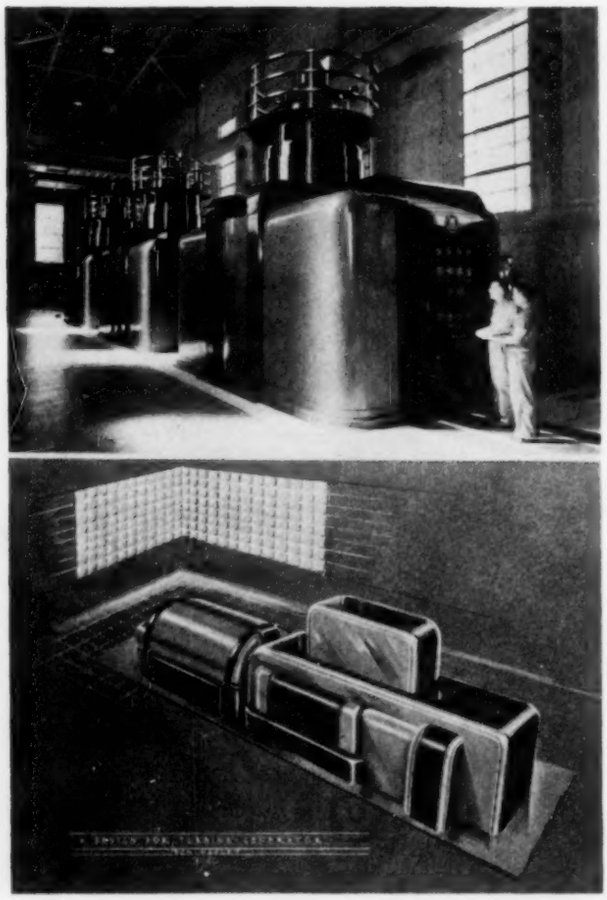


Fig. 10—Looking Into the Future of Modern Turbine-Generator Designs

draftsmen and also to the shop personnel who are later to manufacture this equipment. Meetings are arranged whereby the discussion of design and fabricating procedures can be freely discussed, using the model as a sample, and separating the model into its individual pieces to study particular designs or shapes which must be manufactured.

One other feature which a model tends to enhance is the attractiveness or eye appeal of the appearance of fabricated electrical machinery. In this modern age in which we now find ourselves everything must have an eye appeal or, to use a much-used expression, be "streamlined." In the past the stress has been entirely upon the practical application of the machine rather than its appearance. At present the practical requirements of the machine are no less important, and the design is made on the premises that the machine must satisfactorily fulfil its fundamental engineering uses; but in addition we now add the frosting to the cake in the form of graceful curving structures that really have eye appeal to the layman.

SELECTION OF MATERIALS

First and foremost in the selection of proper and suitable materials for welding, consideration must be given to the chemical composition and physical characteristics of the steel to be used. The steel selected must possess adequate physical properties so that the designs in some instances do not become cumbersome and too heavy through the use of steel of insufficient strength. Next, these steels must be so selected as to give the best welding characteristics. This, in general, means using an inexpensive low-carbon steel of the following chemical analysis with which steel fabricators are familiar:

Carbon	0.10–0.20%
Manganese	0.35–0.60%
Silicon	0.02–0.06%
Phosphorus	0.05 max.
Sulphur	0.05 max.

Usually an attempt is made to select a steel which has good welding characteristics and offers no disadvantages to flame cutting. This is particularly advantageous where so many shapes of unusual contour are flame cut to size. Figure 2 shows a flame-cutting machine in operation cutting four pieces of an identical item simultaneously, later to be used in assembly.

Further, a steel must be selected which is ductile and can be used and formed to the various shapes and contours required for the modern welded structure. This material must be of such a nature that welding will provide strength equal to that of the parent metal and have a ductility equal to that, or greater than that, of the parent metal so that there can be no failures at the junction of the parent metal and the weld.

Last but not least, the material selected for welding must necessarily fall within those standard sizes which can be readily obtained from steel fabricators. Where possible, and it is possible in most cases, the designers are required to use so-called standard materials, which are standard as to size and thickness, because we can buy these in economic quantities and have them available in storage so that production need not be delayed. There are some cases, of course, where unusual shapes or sizes of plates must be purçhased to meet individual requirements. These are the exceptions rather than the rule and those responsible for costs, must work in close cooperation with the design engineer to keep purchases of odd sizes and shapes to a minimum.

MANUFACTURING METHODS

In order to successfully and economically weld electrical machine structures, it is necessary that those items which are part of the complete unit be flame cut, machined, formed or rolled to their correct size in order that they may individually fit into their places of the integral unit. Because of all this additional and related work which must be done, we sometimes lose sight of the importance of welding itself, and yet we have only to recall that all of this forming and fitting would be to no avail if the electric arc-welding process had not been developed to its present perfection. Once the design has been made and accepted for fabrication, it is then the problem of the shop to manufacture the equipment in the best possible manner in the least time for the least cost. Manufacturing methods used, place great importance in the correct fitting and assembling of detailed parts for welding. These methods consume the use of much auxiliary equipment. Figure 3 shows a large turbo-generator frame cover being rolled to the proper radius. Figure 4 shows this same frame cover being hoisted into place to fit snugly around the inner structure of the turbo frame. It is apparent from this photo that the inner structure has been prefabricated, welded and machined prior to the fitting of the unit cover.

Manipulating equipment has been found to be a distinct aid to the welder in positioning the object to its

most accessible position so that he may use down-hand welding for the majority of his work. In addition, proper manipulation facilities will underwrite their initial cost in the reduction of time required for welding. Figure 5 will show a hand-welding application using a manipulator for positioning.

In order to obtain the maximum efficiency in the use of auxiliary manipulating equipment, it is necessary to use this in conjunction with automatic welding equipment. It is particularly advantageous for use in circumferential welding and in some cases can be used for long straight line welds. Figure 6 shows successful automatic welding and manipulator application.

Successful and economic welding is predicated upon the fact that all of the individual elements should fit tightly to one another to provide the least amount of space between pieces. For that reason we have found various welding fixtures to be advantageous in locating and holding individual items in their proper relationship to other items to which they are welded. Figure 7 shows such a welding assembly fixture. You will note that this fixture is universal in that the locating parts may be moved in and out as the size of the welded frame increases. Adjustable fixtures of this nature are a distinct advantage to the welding process.

Proper and economic manufacturing methods require well-designed welding sets applied in such quantities as to allow numerous welders to work on the same structure where this is necessary for immediate production requirements. Adequate instructions for welding operators is necessary for the success of welding fabrication. A welding engineer, who is attached to the shop personnel, and welding instructors as his aids do much to improve the quality of workmanship and appearance of our welds and welded structures.

Inspection provides a very important link in the successful fabrication of welded structures. It is necessary that each of these structures pass visual inspection of the welds for proper appearance and size. Frequently, welds which must conform to pressure requirements of the design must be given a better inspection than is possible through visual check alone. Portable industrial X-ray equipment can best select satisfactory welds. Figure 8 shows a pressure weld undergoing X-ray examination and inspection.

In conclusion the welding operator is necessary for the success of welding fabrication. Summing up for a moment, it is flexible, simple, lends itself to a wide variety of design and is economical. Further its flexibility provides the means to make equipment which not only fulfills its practical and engineering requirements but also begins to show a tendency toward beauty for inanimate objects classed as electrical machinery. Figure 9 was a recent installation using all-welded construction designed in such a way as to portray a pleasing appearance. Figure 10 gives a brief look into the future as to what may be expected from the appearance standpoint of heavy so-called capital good machinery in the electrical equipment industry. This is a turbine-generator unit of the future.

DESIGN AND FABRICATION OF Heavy Rolling Mill Machinery*

By G. W. LINKHAUER†

SOME years ago, our Company began the fabrication of a portion of our product by the use of the metallic arc-welding process. We began by setting up the equipment of a welding shop and the training of its welders, and by instructing the personnel of our Engineering Department during a series of evening meetings. These meetings were presided over by our worthy Vice-Chairman of this session, Mr. R. E. Kinkead. His able instruction in the use of welding symbols on our drawings, and in the methods of simplifying and improving design to accommodate welding procedure has been invaluable to our Company.

Studying the joining of metal parts by arc welding, we find there are a few well established methods of joining plates and shapes. The basic types of joints are the butt joint, the right angle or tee-shaped joint and the lap joint; all other joints are some variation of these three methods.

To organize a method for designing and for fabricating by arc welding, we required a system of symbols for the regularly recurring types of joints. A relation must exist between the needed strength of the joint and the amount of metal necessary to safely do the work required of the welding. Therefore, we must examine the various uses of the weld metal in a joint, and as far as possible analyze the direction of the known or expected stresses in the joint. These variations of the value of deposited metal in a joint, resulting from such analyses, are what increases the number of weld symbols necessary to convey the engineering demands to the welders, and the number of symbols are further augmented by the methods in which the welding is actually to be done.

Welded construction is a substitute for either solid castings or riveted or bolted construction, and we would no more design a welded structure without considering the strength of its welds than we would design a riveted or bolted joint without figuring its strength. We have a series of gages for inspection of the scarfed openings to be filled with deposited metal and others to check the contour and completeness of the weld-metal fillets. This is to guarantee full deposition of the amount of metal required by our Engineering Department. We require our draftsmen to be thorough in the application of weld symbols to the drawings, and encourage a systematic procedure of examining the drawings to assure the existence of all the necessary markings. This can be done by taking each plate or kind of plate in an assembly and being certain the necessary weld symbols are shown, progressing regularly through the structure until all pieces and joints have been considered.

The available engineers and draftsmen usually come from construction companies where riveted joints are used, and they must be taught new conceptions as regards welded joints. This is especially true where more than two pieces meet in a single joint and two or more pieces are parallel to each other. This subject is well

* To be presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† United Engineering & Foundry Co., Pittsburgh, Pa.

illustrated by considering the sketches in Fig. 1. At sketches *a* and *b*, we see the accepted uses of angles for a riveted joint construction. If either of these is used in a welded construction, we have in one case three lines of welding and in the other case, four lines of welding to fasten the joint, but neither of these is a satisfactory joint because of the unwelded corners of plate where failure can begin if transverse work is applied. In sketch *c*, the proper method is shown; a thoroughly welded joint with only two lines of welding, resulting in safe construction and sure economy.

In Fig. 2, we see two parallel plates at right angles to a third member. This construction would be basically wrong because of the unwelded corners which allow movement and eventual failure, but we can improve the

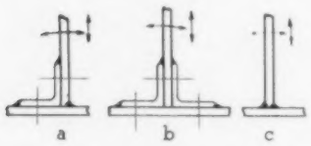
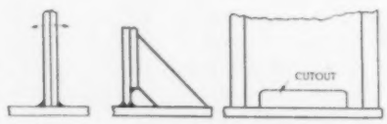


FIGURE 1

FIGURE 2



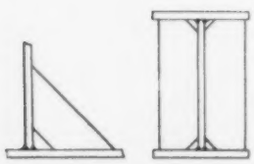


FIGURE 3

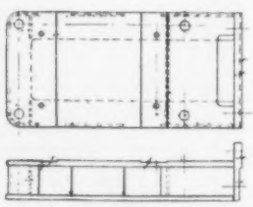
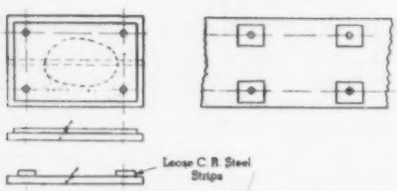


FIGURE 5

FIGURE 4



condition by shortening one of the parallel plates or by cutting away a part of it. The common corner brace preferably should not be fitted and welded into a corner, but should be kept away from the other welding; such braces can often be made of small flat bars as is also shown in Fig. 3.

Avoid large, blister-type pads for a number of economical reasons. First, because of the expense of welding around them; second, because unless they are thick, they will and do bulge up or "blister" causing endless trouble in machining and erection; third, because they do not necessarily cause any less planning than a design without them. See Fig. 4. When planing over this "blister" with a roughing tool, the blister depresses and returns with each stroke of the tool, leaving a bulged surface. Then put a broad nosed finishing tool in the planer to finish this surface, and the unsupported blister will sink down with the first few strokes that pass over it and then stay up, and the tool will plunge and gouge into it usually breaking off the tool and marring the job. If we do get a finish over it without marring the surface and try later to bolt something onto this surface, the pad is thinner over this blister and weak at this point giving poor support to the attached member, often allowing the bolting to pull the attached piece out of alignment. The distance welded around two or four small pads is usually less than the perimeter of the larger pad, and these smaller pieces can be brought down tighter, the area covered by the planer tools is still about the same, or we can plane the parent plate and use standard thicknesses of finished rolled plate or bars as a filler, and the bolts will prevent these pieces from getting away while the bolts are not tightened.

Bent plate corners are usually less costly than welded corners and surely look better, with at least equal strength.

A typical welded motor base is shown in Fig. 5 with bent corners on the vertical plates, avoiding the butt welding of this vertical plate by bringing the ends to access openings for the bolts. Note also the absence of pads for motor feet and for foundation bolts. The design is intended for bolting to an adjacent machine drive, but by duplicating the free end, it can be made for mounting independently on the foundation. This design is a good one from standpoint of cost, utility and machine-shop economy.

In our regular work, we have found it an advantage to have some standardized shapes made of cast steel and usable, in conjunction with rolled shapes and plates, on a great number of structures. Some of these are the cast-steel bolt lugs, lifting lugs and a standardized clamp plate for inspection holes; each made in several sizes.

As to appearance of the structure to be made, we can say this: if only welded structures are adjacent to the piece we are making, then we use the common welded joint construction; if only castings are adjacent to the piece, then we design to conform somewhat to the shapes and appearances of castings; if combined welded and cast shapes are adjacent to the piece we are making, good design will usually result in good appearance. In all cases, we think first of utility, second of shop economy, and third of appearance. Appearance will largely take care of itself if the job is well designed. A good job looks good. In this regard much might be said as to the training of an engineering corps in methods of welding plates and shapes; for instance, by allowing the necessary clearances for the welder and his tools to get readily "to the weld;" by proper location of welds and provision of access openings when necessary. Care in these matters will aid not only in cost reduction, but also in obtaining good appearance.

The I-beam construction is often the simplest strength shape for a beam and is easiest to make by welding. It can be fully stiffened with braces between the flanges and all welds will be readily accessible. If necessary, it can be easily covered for appearance. The I-beam is exceptionally economical if a rolled shape can be used to eliminate the long welds required in a built-up beam, and when a built-up beam is necessary, the long joints between web and flanges will often be strong enough if stitched, to keep down cost.

Although our welding shop is about 75 miles away from the Engineering Department, we nevertheless work in close collaboration with the welding shop and machine shops. We encourage the use of jigs for welded structures, and have often designed with the intention of doing some major machining operations on certain parts before completing the welding. Final welding is done in jig supports kept in contact with the finished surfaces and we have managed to preserve exceptional accuracy of the finished piece.

OUR PART IN NATIONAL DEFENSE

Walter S. Gifford, President, American Telephone and Telegraph Company

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Walter S. Gifford

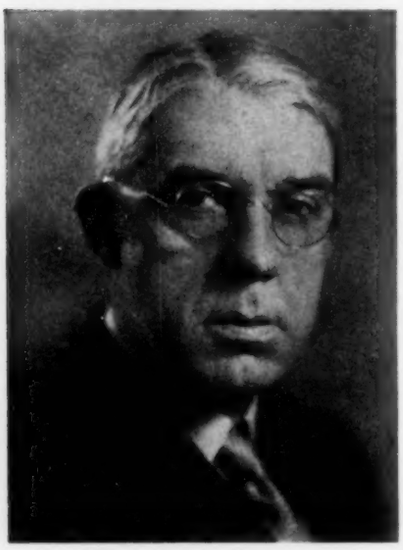
THE BELL SYSTEM IS READY TO DO ITS PART IN THE NATION'S PROGRAM OF NATIONAL DEFENSE

Welding Society ACTIVITIES—Related Events

A MESSAGE FROM OUR PRESIDENT

The Twenty-First Annual Meeting of the AMERICAN WELDING SOCIETY will be held at the Cleveland Hotel, Cleveland, during the week of October 20th. There is every indication that this will be one of the most successful meetings the SOCIETY has ever held. We have already been advised by the Hotel that practically all rooms reserved for the SOCIETY have been taken up. The Editor tells me that he has never seen a finer collection of papers for the Annual Meeting than those which are to be presented this year.

During the year a number of records of



George Terry Horton

the SOCIETY have fallen. Among these we may mention the fact that we now have the largest membership in the history of the SOCIETY, the largest number of Sections, and during the year we have published the largest number of pages in THE WELDING JOURNAL. Our research program supersedes those of any former year. The number of technical reports issued by the SOCIETY, as well as the revenue received from advertising, have surpassed all previous marks.

Collectively, these are indications that the SOCIETY is moving steadily onward just as the wise and far-seeing founders of the SOCIETY have planned.

Each year the Annual Meeting provides an opportunity for a good part of the leaders of the welding industry to get together, talk things over, exchange experiences, participate in technical discussions, attend meetings, visit the Exposition and join in the social functions provided.

Welding is bound to play an important part in the rearmament program and the general industrial progress. Everyone who can possibly attend the Annual Meeting should make plans to do so.

Inasmuch as my administration soon ends, this will be my last message to the membership and I wonder if you all know, Members, Directors, Officers and Staff, how much I appreciate your conducting the affairs of the SOCIETY so well for me. No one knows better than myself how little credit is due me and how much is due our organization.

GEORGE T. HORTON, *President*

NATIONAL METAL CONGRESS AND EXPOSITION

The National Metal Congress and Exposition, combining the metal world's largest industrial exhibit and sessions for principal technological societies dealing with metals, will meet in Cleveland, Ohio, for five days beginning October 21st.

The 1940 Congress and Exposition will be the largest in the twenty-two year history of the event, according to Wm. H. Eisenman, managing director. More than 100,000 square feet of exhibit space have been taken by exhibitors representing every branch of the metals and associated industries. Extensive technical programs of the American Society for Metals, THE AMERICAN WELDING SOCIETY, The Wire Association and the Iron and Steel division and the Institute of Metals division of the American Institute of Mining and Metallurgical Engineers will be held in conjunction with the show. Technical sessions are generally scheduled to be held in three Cleveland hotels as well as at the larger meeting rooms in the Municipal Auditorium.

The theme of the 1940 National Metal Congress and Exposition is "NEW AIDS TO PRODUCTION"—an especially appropriate keynote by virtue of the gigantic defense program now under way. Every item and method to be seen will have direct relation to the preparedness program.

The welding industry will be represented at the metal show by all types of welding: arc, spot and resistance; by gas welding and oxyacetylene gas and gas-cutting equipment. Included in this group are electrodes and electric controllers as well as various grades of welding wire for gas and electric welding.

Heat-treating furnaces of all types will be on display: salt bath, annealing-electric, gas and oil fired; induction, atmospheric-controlled furnaces of all types and sizes. In addition there will be furnaces and heating equipment for heating rivets and bars; industrial oil-heating apparatus and various insulating materials for furnaces and electric heating elements.

In steels visitors will see tool steel, stainless steel, construction steel, valve steel for aircraft and automotive units, heat- and corrosion-resistant alloys, sheet, strip and high-speed and other steels. These will be shown in finished form and through products made from them.

In the non-ferrous field there will be aluminum, aluminum alloys, magnesium, magnesium-aluminum alloys, copper, brass, bronzes, zinc, die casting shapes and forms, non-ferrous wire and other alloys cast and wrought. Machinery for die casting, wire drawing and spring forming will be shown.

The gas industry will be represented by gas-fired, heat-treating furnaces and many gas-heating industrial appliances.

Testing equipment to indicate hardness, tensile, torsional strength, fatigue and many other properties of metals will be demonstrated.

Temperature recording and control equipment will include devices for indicating, recording and controlling temperatures.

Tools of all types will be on exhibit. They include hack saws and files, electric drills, diamond tools, tungsten carbide cutters, diamond test cutters and reamers. Included in this group are abrasive cutting machines and abrasive wheels.

Plating processes and materials to be shown at the N. M. C. E. include plating equipment generators, plating barrels, polishing lathes, induction heating and hardening equipment and methods. Methods in castings will be illustrated, dealing with malleable heat-treated and heat-corrosion resistant items.

Hundreds of other aids to better production will be shown. They include heat-treating salts, carburizing salts, compounds and supplies. Noble metals will be shown in new uses. Handling equipment such as cranes, trucks and hoists are included. Pieces of various optical measuring, metallographic and spectrographic equipment, blue-printing machinery and drafting-room equipment are to be exhibited. Laboratory equipment to be shown includes polishing machines,

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chemical determinators and other items for chemistry laboratory work.

Ferro alloys for production purposes will include nickel, molybdenum, vanadium, chromium, manganese and many other metals in this field.

Fastener items to be shown include nuts, bolts, screws, rivets and lock washers. Hard-surfacing alloys for various parts of industrial machinery will be on display.

Petroleum products, quenching oils, rust preventatives and metal-cleaning compounds will be shown. Sand-blast equipment and detergents will be included.

Industrial appliances to be shown will include safety shoes, masks, goggles and other safety equipment as well as water-dispensing equipment.

X-ray equipment, turbo compressors and metal cloth are included in the miscellaneous classifications.

Trade and business publications in the metals and associated fields have made arrangements to provide various informational services at their exhibit booths.

Cleveland Auditorium

Trade and professional associations, allied with the metals field, will be represented by exhibit booths.

Technical programs arranged by the four societies are larger this year than ever before.

This year's National Metal Congress and Exposition will be the largest in history—20% larger than the 1939 Exposition in Chicago. It will cover the upper and lower levels of the Cleveland Auditorium's underground Exposition Hall and Annex as well as the North Hall and the Main Exhibition Hall.

Plan to Attend

Annual Meeting

Cleveland Ohio

Headquarters, Hotel Cleveland

TENTATIVE PROGRAM LADIES ENTERTAINMENT

Headquarters and Registration—Cleveland Hotel.
Hours—9:00 A.M.–4:00 P.M. Monday–Thursday.

Sunday Oct. 20th—President's Reception, Cleveland Hotel 5:00–7:00 P.M.

Monday, Oct. 21st—"Get Acquainted Tea"—Cleveland Hotel 3:00–5:00 P.M.
In Charge—Mrs. R. E. Kinkead, Mrs. J. F. Lincoln and Mrs. E. R. Benedict.
Hostesses at Registration Desk—Mrs. Pierre Champion, Mrs. J. F. Collins, Mrs. H. H. Dyar.

Tuesday, Oct. 22nd—Luncheon and Bridge Party at University Club 12:30 P.M.
In Charge—Mrs. Lorn Campbell, Mrs. I. B. Hexter, Mrs. H. H. Dyar.
Hostesses at Registration Desk—Mrs. A. E. Gibson, Mrs. E. P. W. Smith.

Wednesday, Oct. 23rd—Bus trip on West Side with visit to dress factory. 2:00 P.M.
Womens Stag Party, Alpine Village 7:00 P.M.
In Charge: Mrs. F. J. Collins, Mrs. J. Morrill, Mrs. Pierre Champion, Mrs. A. F. Davis, Mrs. C. M. Taylor.
Hostesses at Registration Desk—Mrs. Lorn Campbell, Mrs. I. B. Hexter, Mrs. E. T. Scott.

Thursday, Oct. 24th.—Brunch at Higbee's Store—11:00 A.M. Tour of store and style show—conjunction with Society Metals.
In Charge: Mrs. A. E. Gibson, Mrs. E. W. P. Smith, Mrs. F. C. Loweth.
Hostesses at Registration Desk—Mrs. J. Morrill, Mrs. A. F. Davis, Mrs. L. Aurbach.
Annual Banquet—7:00 P.M.

Friday, Oct. 25th—No entertainment planned. Left free for shopping.

Ladies Committee

Mrs. Fred L. Plummer, Chairman

Mrs. L. Aurbach	Mrs. I. B. Hexter
Mrs. E. R. Benedict	Mrs. R. E. Kinkead
Mrs. Lorn Campbell	Mrs. J. F. Lincoln
Mrs. Pierre Champion	Mrs. F. C. Loweth
Mrs. F. J. Collins	Mrs. J. Morrill
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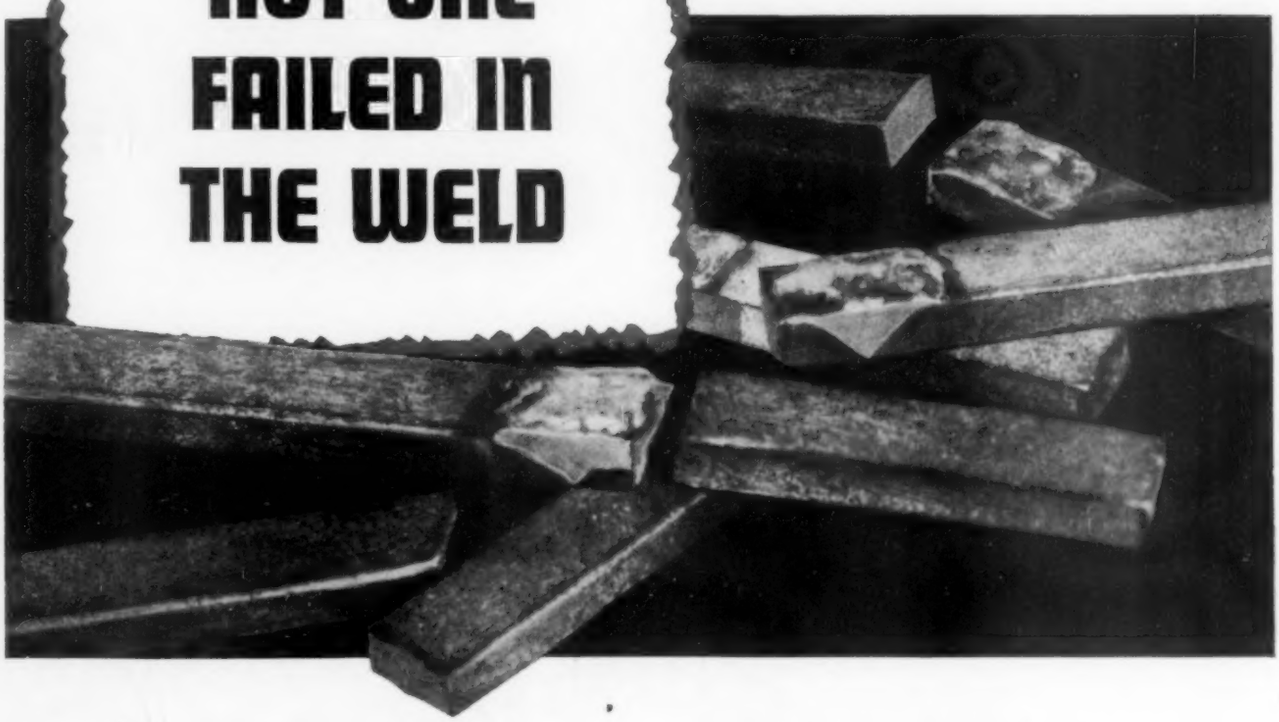
All failed in the parent metal

NOT ONE FAILED IN THE WELD



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OUR NEW PRESIDENT

Glen F. Jenks

Our incoming President is well known to a very large number of the working members of the AMERICAN WELDING SOCIETY. Colonel Jenks has been active in many of the affairs of the SOCIETY, notably its technical and research work. In addition, he has found time to give of his wise council in administrative matters and in the presentation of papers before various Section meetings. During the coming year there is every reason to believe that the steady progress of the SOCIETY will continue onward under his guiding hand.

Colonel Jenks was born at Deansboro, N. Y., June 13, 1880. Graduate of Hamilton College (Clinton, N. Y.), B.S. 1901, M.S. 1904. Graduate of Army War College (1924) and of Harvard Business School (M.B.A. 1930). Entered the Army as a 2nd Lieutenant, Artillery Corps, 1901, and detailed in the Ordnance Department, 1903. During the World War served as Colonel, National Army, at Headquarters A. E. F., and at Headquarters Service of Supplies A. E. F. in charge of technical work in heavy artillery in the Office of the Chief Ordnance Officer and for two months prior to the Armistice as Chief Ordnance Inspector of Artillery at Headquarters First Army. Was decorated by the French Government as Officer of the Legion of Honor and was awarded the Distinguished Service Medal by the American Government.

Since the war served in the Office of the Chief of Ordnance in charge of engineering

Glen F. Jenks

and production of artillery material, and later in the 8th Corps Area as Chief Ordnance Officer, and at Rock Island Arsenal for two years as Production Manager. Was at Watertown Arsenal as Director of Research for two years and then in command from 1932 until 1937, when assigned to duty in the office of the Chief of Ordnance, U. S. Army. Promoted to the grade of Colonel, Ordnance Department, November 1, 1933.

Member of A. W. S., A. S. M. E., A. I. M. E., A. S. M., A. S. T. M. and S. A. E. Fellow A. A. A. S.

Member of Engineering Foundation Welding Research Committee and Chairman Industrial Research Division of that committee. Member of the Joint Research Committee on Effect of Temperature on the Physical Properties of Metals and of various technical committees of the A. W. S., A. S. T. M. and A. S. A. Chairman of A. S. T. M. Committee E-9 on Research.

Vice-President A. W. S. 1937–1939 and Director-at-large A. W. S. 1939.

OUR FIRST VICE-PRESIDENT

Klaus L. Hansen

Klaus Lobeck Hansen, consulting engineer, Harnischfeger Corporation, Milwaukee, Wis., has been elected to serve as the First Vice-President of the Society. He was born in Sandefjord, Norway, September 14, 1882, and came to the United States in 1901. He was employed by the National Stamping Works and the Western Electric Company, both at Chicago, Ill., before entering the University of Illinois where he studied electrical engineering 1903–1905. After several months with the Chicago Edison Company, he was employed by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1906 and continued with the company until 1919, his last position being designing engineer on D.C. apparatus.

While in the employ of the Westinghouse Company Mr. Hansen became interested in design of arc-welding generating equip-

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Klaus L. Hansen

ment. In 1916 and 1917 he worked on design of constant potential generators, and somewhat later developed and designed the first single-operator set marketed by the Westinghouse Company. In 1919 he went with the Mechanical Appliance Company (later the Louis Allis Company), Milwaukee, as designing engineer, later becoming chief engineer. He left the company in 1921 to engage in consulting and development work on his own patents. He invented the Hansen arc welder, and in its manufacture and sale was associated with the Northwestern Manufacturing Company, Milwaukee, from 1924 to 1932, when it was taken over by the Harnischfeger Corporation. He holds patents on various arc-welding processes and joint patents on induction motors, and has published a number of technical papers, chiefly concerned with welding. He has been a member of the Institute's electric welding committee 1930 to date (chairman 1932–1934), was chairman of the Milwaukee Section 1933–1934, and chairman of the 1937 A. I. E. E. summer convention committee. He is at present serving as vice-president of the A.W.S. representing its Middle Western District.

OUR SECOND VICE-PRESIDENT

David Arnott

Our Second Vice-President has been very active in the SOCIETY since its early days. He has been extremely helpful in its technical activities relating to ship welding. He has delivered a number of papers before the various Sections of the Society and is author of an important chapter of the Welding Handbook. Mr. David Arnott has been a strong supporter of the research activities of the SOCIETY and at the present time is Chairman of the A. W. S. Committee on Welding in Marine Construction. He has also served on the Executive Committee of the Society.

Mr. Arnott was born in Glasgow, Scotland, 1878. He is a graduate of the Royal Technical College, Glasgow, and received his apprentice training as a ship welder with the Fairfield Shipbuilding & Eng. Co., Ltd., Glasgow. He has served as Surveyor, British Corporation Register of Shipping and Aircraft from 1901 to 1917, at head office in Glasgow. He was also Principal Surveyor for Canada, British Corporation Register of Shipping and Aircraft, from 1917 to 1918, stationed at Toronto. Later he became Deputy Chief Surveyor, American Bureau of Shipping, from 1918 to 1925, New York. In 1925 he became Chief Surveyor of the American Bureau of Shipping, a position which he holds at the present time. To these duties were added those of Vice-President of the American Bureau of Shipping in 1938, which position he also now holds.

His technical society affiliations are quite numerous and include: Council Member, Society of Naval Architects &

David Arnott

Marine Engineers; Member, Institution of Naval Architects; Member, British Institute of Welding; Technical Advisor to U. S. Delegation, International Safety of Life at Sea Convention 1929; U. S. Delegate to International Load Line Convention 1930. Mr. Arnott became a naturalized citizen of the U. S. A. in 1924.

OUR DISTRICT VICE-PRESIDENTS

New York and New England—P. J. Horgan

Pat Horgan, as he is known to all of his friends, has served as Chairman of the Boston Section and his outstanding success in that capacity led to his election as District Vice-President. Pat was born, reared and raised in Wakefield, Mass., and graduated from the high school there. He is also a graduate of the General Electric Apprentice Course in drafting and attended the Lowell Institute for Industrial Foremen. His industrial connections include the Heinze Electric Company of Lowell, Mass., on Airplane Gas Engine design. Later, for a 13-year period, he was connected with the United Shoe Machinery Co., Beverly, Mass. He has served as Foreman on Experimental Drafting and was a member of committees on design. Then followed a 17-year period with the General Electric Company including assignments on turbine manufacturing and Assistant to General Superintendent of Foundries. For the past 14 years Pat has been actively associated with all the welding problems at the Lynn Works of the General Electric Company.

Patrick J. Horgan

* * *

Middle Eastern—E. T. Scott

Mr. E. T. Scott has been actively interested in the Cleveland Section for the past fifteen years. He has served as Secretary-

E. T. Scott

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★ COVERED WELDING ELECTRODES

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Treasurer of this Section for approximately ten years. He was also honored with the office of Vice-Chairman for the past two years. Mr. Scott is interested in the welding field from an educational standpoint. As President of the Cleveland School of Welding he has been training operators in the Cleveland district for the past seventeen years. His likable personality and his forcefulness have led to his selection as Regional Vice-President of the Middle Eastern District. We can be sure that Mr. Scott will do everything possible to further the interest of the SOCIETY in this office.

* * *

Middle Western—D. H. Corey

Don Corey as he is known to his friends is one of the modest pillars of the AMERICAN WELDING SOCIETY. He has served as Secretary of the Detroit Section and as its Chairman. He has been active on a number of technical committees of the SOCIETY and is co-author of one of the chapters of the Welding Handbook. Don was born in Winona, Minnesota, in 1900; graduated from the University of Wisconsin with the degree of B.S. in Electrical Engineering; and has been employed by The Detroit Edison Company since then, with the exception of six months immediately following graduation. His positions there have been: Test Engineer in the Production Department, Mechanical Engineer in the Research Department, and Welding Engineer, the latter position having been held since 1933, just prior to the adoption by the company of welding in the erection of high-pressure piping. Don has been quite active in following welding for his company.

D. H. Corey

* * *

Pacific Coast—L. W. Delhi

Mr. Delhi was born in Arizona, November 1892, and is of Danish extraction. He attended Throop Polytechnic and U. S. C. Mr. Delhi was unable to complete his university work and turned to professional baseball for four years before resuming engineering with the Nevada Consolidated Copper Co., at Ray, Arizona, which position he held for four years. He then spent three years in engineering work and contracting in Southern California and about sixteen years ago joined the Western Pipe & Steel Company. He is a member of the Olympic Club, Lakeside Gold & Country

L. H. Delhi

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11 to 13½% Manganese Nickel Steel

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1/2" PLATES WELDED

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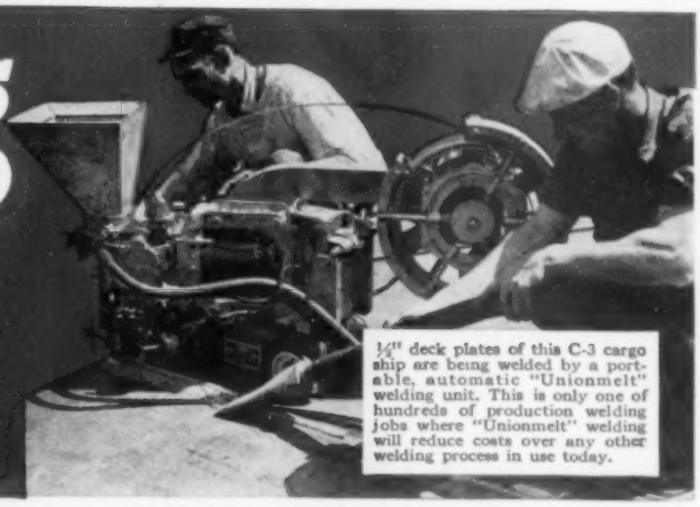
·IN ONE PASS·



½" deck plates of this C-3 cargo ship are being welded by a portable, automatic "Unionmelt" welding unit. This is only one of hundreds of production welding jobs where "Unionmelt" welding will reduce costs over any other welding process in use today.

"UNIONMELT" PROCESS with Westinghouse FLEXARC Welders

WELDS MEET ALL CODE REQUIREMENTS
1/16" TO 1½" PLATES BUTT-WELDED IN ONE PASS
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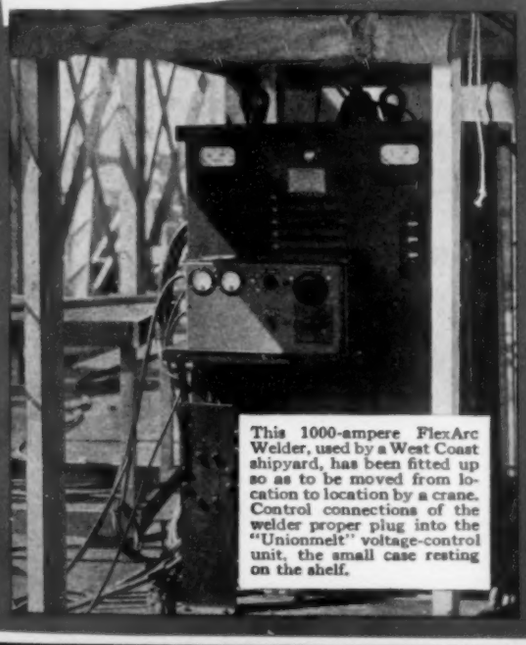
For full information, see your Westinghouse representative, or write Department 7-N, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pennsylvania.



This 1000-ampere FlexArc Welder, used by a West Coast shipyard, has been fitted up so as to be moved from location to location by a crane. Control connections of the welder proper plug into the "Unionmelt" voltage-control unit, the small case resting on the shelf.

as much as

20 TIMES FASTER

than former methods

A license from The Linde Air Products Company to use the "Unionmelt"* welding process is enabling many manufacturers to speed production, cut welding costs. Frequently, it makes possible the use of welding in place of more cumbersome methods of fabrication.

For this process, developed by The Linde Air Products Company, Westinghouse makes the complete line of a-c and d-c welders and other electrical equipment including transformers, switches, capacitors and motors.

The equipment most commonly used is a specially developed FlexArc Transformer Welder. It is a heavy-duty, transformer type, with infinite-step motor-driven reactor. This welder is continuously adjustable under load, meets every requirement of the "Unionmelt" equipment with which it is used, plus every requirement of cost-conscious management.

Because of the current-control mechanism developed by Westinghouse, maintenance cost is negligible. With an efficiency of about 92% (93.5% at 20% load) it saves power. Its construction—with liberal insulation, rugged bracing, ample cooling ducts—assures long life. Extra refinements, such as the dial for presetting current, the plug-in controls, etc., mean extra convenience and speed in setting up.

FlexArc Welders are used by the majority of licensees of the "Unionmelt" process.

*The word "Unionmelt" is a registered trade mark of The Linde Air Products Company.

J-70278

Westinghouse Flexarc Welders

WESTINGHOUSE ELECTRIC

Club, Astronomical Society of the Pacific and the Seismological Society. It may be added that for the entire sixteen-year period with the Western Pipe & Steel Company the major problem has been the sales, engineering and mechanical development of welded products.

* * *

Southern—O. T. Barnett

Ever since Mr. Barnett became connected with the welding industry he has been a member of the AMERICAN WELDING SOCIETY. For the first two years following its organization he was Chairman of the Oklahoma City Section, one of the active Sections in the southwest.

O. T. Barnett

Mr. Barnett graduated from Armour Institute of Technology in June 1933 with a B.S. degree in Chemical Engineering. Following graduation, he was employed by the Carnegie-Illinois Steel Corporation in the metallurgical control department. Here he gained first-hand experience in the melting and processing of iron and steel. From the Carnegie-Illinois Steel Corp., he went to work for Black, Sivalls & Bryson, Inc., Oklahoma City, Oklahoma, as metallurgist. This was in April 1936. In July 1938 all shop inspection was added to his other duties.

In addition to his membership in the A. W. S., he holds memberships in the American Society for Metals and the American Society for Testing Materials.

OUR NEW DIRECTORS

A. G. Bissell

A. G.'s first connection with welding dates from May 20, 1918, when he was detailed to investigate arc welding and its possible use in naval construction at the Puget Sound Navy Yard. As Metallurgist for that Navy Yard, he carried on the early development work, training of operators and organization of the Hull Division

A. G. Bissell

Welding Shop. While at that Yard, he prepared a thesis, "The Application of Arc Welding to Steel Ship Construction," which was presented in June 1920 to the University of Washington, Seattle, in fulfillment of the requirements for the Degree of Chemical Engineer. It is believed that this was the first thesis on welding to be accepted for an advanced degree. Curiously enough, Mr. W. Spraragen, Technical Secretary of the SOCIETY, who was teaching at the university at that time, was in charge of this thesis.

The sojourn at the Navy Yard was completed in October 1921. The next major connection involving welding occurred on March 23, 1923, when he entered the General Engineering Department of the Westinghouse Electric & Mfg. Co., at East Pittsburgh, as an arc-welding engineer. On this job he did considerable work on the early development of structural steel welding, participating in the design and erection of the first all-welded buildings at East Pittsburgh, in July 1926, and the first all-welded through plate girder railroad bridge at Turtle Creek, Pa. During his connection with Westinghouse he spread the gospel of arc-welded structural steel and automatic arc welding throughout the country from Boston to Los Angeles, and Norfolk to Seattle. The Westinghouse connection ended in November 1928 when Bissell decided to break into the consulting game on the Pacific Coast. His next connection was with the Star Machinery Company of Seattle, as Sales Engineer, handling Westinghouse welding equipment.

His present connection with the Bureau of Construction and Repair was made on October 15, 1936. At the present time he is in charge of the supervision of the Welding and Castings Section of the Bureau of Ships. A. G. has served on literally dozens of important technical committees of the AMERICAN WELDING SOCIETY. He was one of the prime movers in organizing the Washington Section of the A. W. S. and a strong factor in building it up to its present unique high standing. He has assisted in the lecture course presented by the Washington Section. The Society is indeed fortunate to secure the services of Mr. Bissell in the capacity as Director.

J. H. Deppeler

Mr. Deppeler is one of the charter members of the AMERICAN WELDING SOCIETY. He was active with the old Emergency Fleet Corporation Welding Committee. "Dep" was the second president of the AMERICAN WELDING SOCIETY and has served on the Board of Directors for many years and his re-election is not a great surprise.

Mr. Deppeler graduated from Stevens Institute of Technology with the degree of M.E. in 1906. He became interested in Oxyacetylene cutting work while employed by the New York Central-Hudson River Railroad, and utilized this in cutting down their train shed, cutting 100-ft. arches into seven pieces and lowering them in flat cars without interrupting the traffic in Grand Central. This was done in 1907, when he immediately affiliated with the Oxyacetylene welding industry and the sale of the oxygen and acetylene generators.

Mr. Deppeler is employed by the Metal & Thermit Corporation since July 1912, successively as superintendent and chief engineer of the corporation.

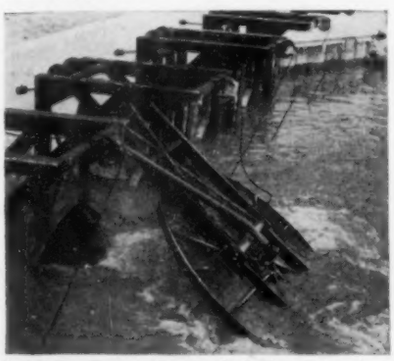
Mr. Deppeler has served on many technical committees of the Society. His particular strong point is the chairmanship of the Filler Metal Specifications Committee.

J. H. Deppeler

Mr. Deppeler has delivered literally dozens of addresses before Sections of the AMERICAN WELDING SOCIETY and its national meetings. He has published many important technical papers dealing with Arc and Thermit welding. He represents the Society on several important technical committees of other organizations. He is a member of the A.W.S. Safety Committee and has been an untiring worker on behalf of the sound development of welding. Dep is co-author of two important chapters of the A.W.S. Welding Handbook and has assisted in the review of several others. He is regarded as one of the leading welding experts in the welding field.

Welded, Rolled Steel Construction

Snow flies off the road when this plow goes into action. By using special steels in strategic places, the Roto Wing Company was able to save 1000 pounds in deadweight without sacrificing strength in their new snow plow. The unit shown weighs less than 1300 pounds as against a former 2300-pound structure made from structural quality plates. 12-gauge U·S·S MAN-TEN was used for the mouldboard and 3/16" MAN-TEN for bracing back of the wing portion.



U·S·S COR-TEN used extensively in vast project to reclaim Everglades. Here's one of the 60 gates which shut out salt water and keep the fresh water level right for farming in the Dade County water control development in Florida. 936 linear feet of 72" culvert pipe, 26 swing gates and four turbine pumps, each with a capacity of 80,000 gallons, used in this project, were built of COR-TEN to better resist corrosion, to reduce wear and prolong life.

Shovels take a beating moving limestone rock. When equipment like this is built for gruelling work, designers know that Rolled Steel construction, with the use of special steels in the vital parts, will make it stronger and longer-wearing. Here, special steels and welded construction add to shovel life, keep the dipper from wearing out so quickly, and make the dipper boom stronger.

Look for this trade-mark on steel products. It is your assurance of quality and full value for your money.

Stands the Gaff!

Saves time and money, does more work, lasts longer in equipment that moves snow, mud, water and limestone rock

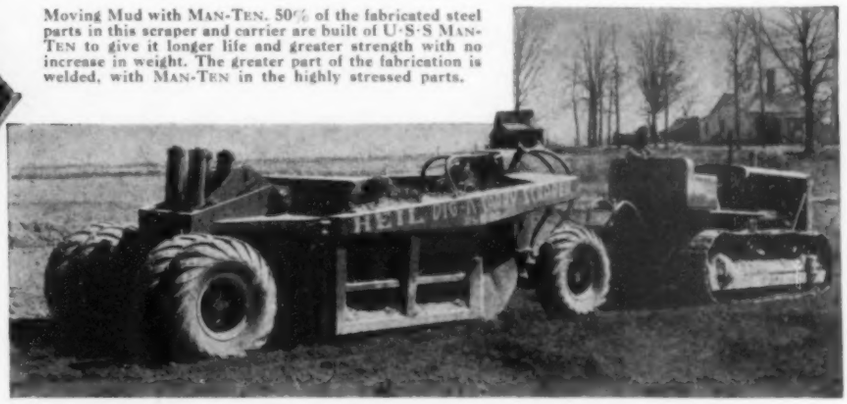
MOVING tons of earth, rock, snow, countless gallons of water, day in and day out, calls for equipment that can take it. Equipment that can stand up under severe stresses and strains. Equipment that can resist continuous abrasion—that can operate economically and efficiently.

Here again as in many other types of equipment, both heavy and light, performance proves that far more satisfactory results are obtained with welded, rolled steel construction. By using rolled steel, you can put special steels where they will do the most good and by so doing, add strength where you want it without increasing weight . . . and give vital spots extra resistance to impact, wear, heat, corrosion, abrasion and vibration.

For rolled steel construction we offer special steels in widest range. U·S·S COR-TEN to resist corrosion; U·S·S COR-TEN and U·S·S MAN-TEN to increase strength without adding weight; U·S·S Abrasion-Resisting Steel for use where abrasive conditions are severe; U·S·S Heat-Resisting Steels to combat high temperatures; U·S·S Stainless Steel to improve appearance and resist corrosion of all kinds; and U·S·S Carilloy Alloy Steels to carry tremendous bearing pressures.

Our steel specialists are at your service. They will be glad to show you—without obligation—how and where to use these steels in your equipment to best advantage.

Moving Mud with MAN-TEN. 50% of the fabricated steel parts in this scraper and carrier are built of U·S·S MAN-TEN to give it longer life and greater strength with no increase in weight. The greater part of the fabrication is welded, with MAN-TEN in the highly stressed parts.



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United States Steel Export Company, New York

UNITED STATES STEEL

Harold O. Hill

Harold O. Hill recently elected Director-at-Large, of the AMERICAN WELDING SOCIETY, is Assistant Chief Engineer, Fabricated Steel Construction, of the Bethlehem Steel Company, at Bethlehem, Pa. Born in Ontario, Canada, he was educated at the University of Toronto, from which he received the degree of B.A.Sc. in Mechanical Engineering.

Harold O. Hill

He commenced his engineering career with the Riter-Conley Company of Pittsburgh, Pa. Here he served in many capacities and was Chief Engineer when this company was merged into McClintic-Marshall Co. He became Assistant Chief Engineer of the enlarged company in charge of the engineering on tank and plate-work.

When McClintic-Marshall Co. was merged with the Bethlehem Steel Company in 1931 he continued his same duties with the Bethlehem Steel Company.

Other engineering activities include the chairmanship of the A. W. S. Committee, which prepared "Tentative Rules for Field Welding of Storage Tanks;" Chairman of the A. P. I.-A. W. S. Conference Committee on the Welding of Storage Tanks; Member of the A. W. S. Nomenclature Committee; Member of the A. W. S. Electrode Committee; Member of the A. W. S. Standard Qualification Committee; Member of the A. W. W. A. Committee which prepared Specifications for the Construction of Standpipes and Elevated Tanks; Member of the A. P. I., A. S. T. M., A. I. E. E., A. S. C. E. and a registered structural engineer in the State of Pennsylvania.

Mr. Hill has been a member of the AMERICAN WELDING SOCIETY for nine years.

* * *

E. L. Mathy

Mr. Mathy has been actively engaged in the welding industry since 1917 and originally had his own business manufacturing in Oakland, California, acetylene-gas generators and welding and cutting torches.

E. L. Mathy

He spent approximately five years with the Air Reduction Sales Company from 1923 to 1928. Beginning with 1928 he has been associated with Victor Equipment Company in the capacity of First Vice-President and now is devoting a considerable amount of time to the composing and writing of all of this latter company's printed matter, advertising and general publicity.

He is a past-president of the Industrial Marketers of Northern California and a director of the National Industrial Advertisers Association. He is also a director in the San Francisco Sales Managers Association and one of the founders of the "Man Marketing Clinic" of San Francisco.

He is a member of the Orinda Country Club, the San Francisco Commercial Club, the Commonwealth Club of California and past-president of the Orinda Board of School Trustees.

Mr. Mathy has attended the meetings of the San Francisco Section of the AMERICAN WELDING SOCIETY since the first day of its founding—in 1922.

NAVAL ARCHITECTS AND MARINE ENGINEERS SOUGHT BY GOVERNMENT

In connection with the national Defense Program the United States Civil Serviee Commission is endeavoring to secure well-qualified naval architects and marine engineers for Government service. Examinations have been announced covering two grades in naval architecture and marine engineering, as follows: Principal, $5600 a year; senior, $4600 a year. The salaries are subject to a retirement deduction of $3\frac{1}{2}$ per cent. Applications may be filed with the Commission's Washington office until June 30, 1941. Qualified persons are urged to apply at once. Examinations for lower-grade naval architect and marine engineering positions were announced in June and the Commission is still accepting applications for these positions.

For both the marine engineer and naval architect examinations applicants must have completed a 4-year college course in engineering or naval architecture, except that experience in engineering, naval architecture or shipbuilding may be substituted for this requirement if a sufficient amount of it has been in technical work of professional grade. In addition, applicants for the naval architect positions must have had professional naval architectural experience, except for the partial substitution of graduate study in naval architecture; applicants for the marine engineer positions must have had professional engineering experience partly in marine engineering, except that certain substitution of graduate study in engineering or marine engineering may be allowed for part of the experience. Applicants will not be given a written examination but will be rated on their qualifications as shown in their applications and on corroborative evidence.

Further information regarding the examinations and the detailed requirements are given in the formal announcements. Announcements and application forms may be obtained from the Secretary of the Board of U. S. Civil Service Examiners at any first- or second-class post office, or from the U. S. Civil Service Commission, Washington, D. C.

DR. J. C. HODGE

Announcement is made of the election of James Campbell Hodge as Vice-President and Director of the Wellman Engineering Company, Cleveland, Ohio.

Dr. Hodge received his B.S. degree from Case School of Applied Science in 1923, majoring in metallurgy. For four years afterward he was associated with Bennett and Christensen, consulting chemists and metallurgists, serving foundries in Ohio and Indiana.

J. C. Hodge

OPERATORS WILL LIKE

THE NEW

WILSON "HORNET"*

They helped design it

The new Wilson "Hornet" is the answer to what operators all over the country have suggested toward the development of a sturdy arc welding generator. » » » Simple to operate with no delicate parts to get out of order, yet complete in every detail . . . capable of doing any job that comes into the shop . . . output controlled by means of a sturdy handwheel. Maintains a constant arc which leaves the operator free to do what the machine was primarily designed for . . . namely: to make a better weld. *TRADE MARK

WRITE FOR YOUR COPY
of the new Wilson "Hornet" bulletin featuring the newest of . . . "the machines that make the arc behave."

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and METALS CO., INC.

***General Offices:* 60 East 42nd Street, New York, N. Y.**

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He joined the Babcock & Wilcox Company in Barberton, Ohio, in 1927, as a metallurgist, where he developed and perfected the process of welding used by Babcock & Wilcox Company in the Welding of boiler drums and other important constructions, such as the power penstocks for Boulder Dam. He was closely associated with discussions which led to the adoption of fusion-welded boiler drums by the U. S. Navy in 1930 and to formulation of welding rules by the Boiler Code Committee of the American Society of Mechanical Engineers in 1931. In 1932 he was appointed chief metallurgist of the Babcock & Wilcox Company.

He continued his metallurgical studies at Harvard University between 1931 and 1933. His doctorate was obtained there under the late Professor Albert Sauveur. Since then he has been closely associated with the development of low-alloy constructional steels and of the various heat-resistant and corrosion-resistant steels, particularly with relation to their weldability.

Dr. Hodge is widely known in industry. He has served on technical committees of the American Society for Testing Materials, on the Boiler Code Committee of the American Society of Mechanical Engineers, the Welding Research Committee of the Engineering Foundation, the AMERICAN WELDING SOCIETY and the American Petroleum Institute.

He was joint recipient of the J. F. Lincoln Gold Medal Award of the AMERICAN WELDING SOCIETY in 1938 for the best paper representing original contribution to the advancement of the use of welding.

The problems of metallurgy in welding and the selection of special steels for specific uses enter into all Wellman engineered equipment, and for this work Dr. Hodge's training and experience could not have been better suited.

NEW JERSEY'S KEEL LAID IN CEREMONY

Dedicated to "the preservation of peace in our hemisphere," the 45,000-ton battleship *New Jersey* began to take shape Sept. 16th at the Philadelphia Navy Yard with the welding of two sections of its massive keel by Charles Edison, former Secretary of the Navy.

The keel-laying ceremony, held in the presence of about 8000 of the navy yard employees during the luncheon period, was one of two events important to the national defense program which took place in this city during the day.

Naval regulations kept the public from the navy yard during the laying of the *New Jersey's* keel. Following addresses by Mr. Edison and Governor Moore, who were introduced by Louis Compton, Assistant Secretary of the Navy, Mr. Edison stepped from the platform and put on a welder's mask and yellow leather gloves.

Crouching in Shipway No. 2, which had been lengthened 100 feet to accommodate the keel of the biggest ship ever to be laid down in the Delaware River, he grasped an electrode holder and joined two of the dreadnought's giant plates.

Thus the Navy won nearly a six-week jump on the start of construction of the *New Jersey*, a sister ship of the *Iowa*, the keel of which was laid at the New York Navy Yard on June 27th. It had been intended originally to lay the New Jersey's keel on Navy Day, Oct. 27th. It is the first of four 45,000-ton vessels for which contracts have been let to the Philadelphia Navy Yard.

The *New Jersey* is expected to require nearly four years to build and to cost about $93,000,000.

WELDING SPEEDS PRODUCTION FOR NATIONAL DEFENSE

Production for National Defense could be speeded up immensely and the five- to seven-year period estimated time for completing the Defense Program could be greatly shortened by full utilization of welding, according to figures recently released by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

Battleships, destroyers, submarines, aircraft, tanks, gun mounts, scout cars, tractors, trucks, railway artillery, as well as industrial equipment for armament production, could be produced in 30% less time than required for conventional methods and at approximately similar cost savings.

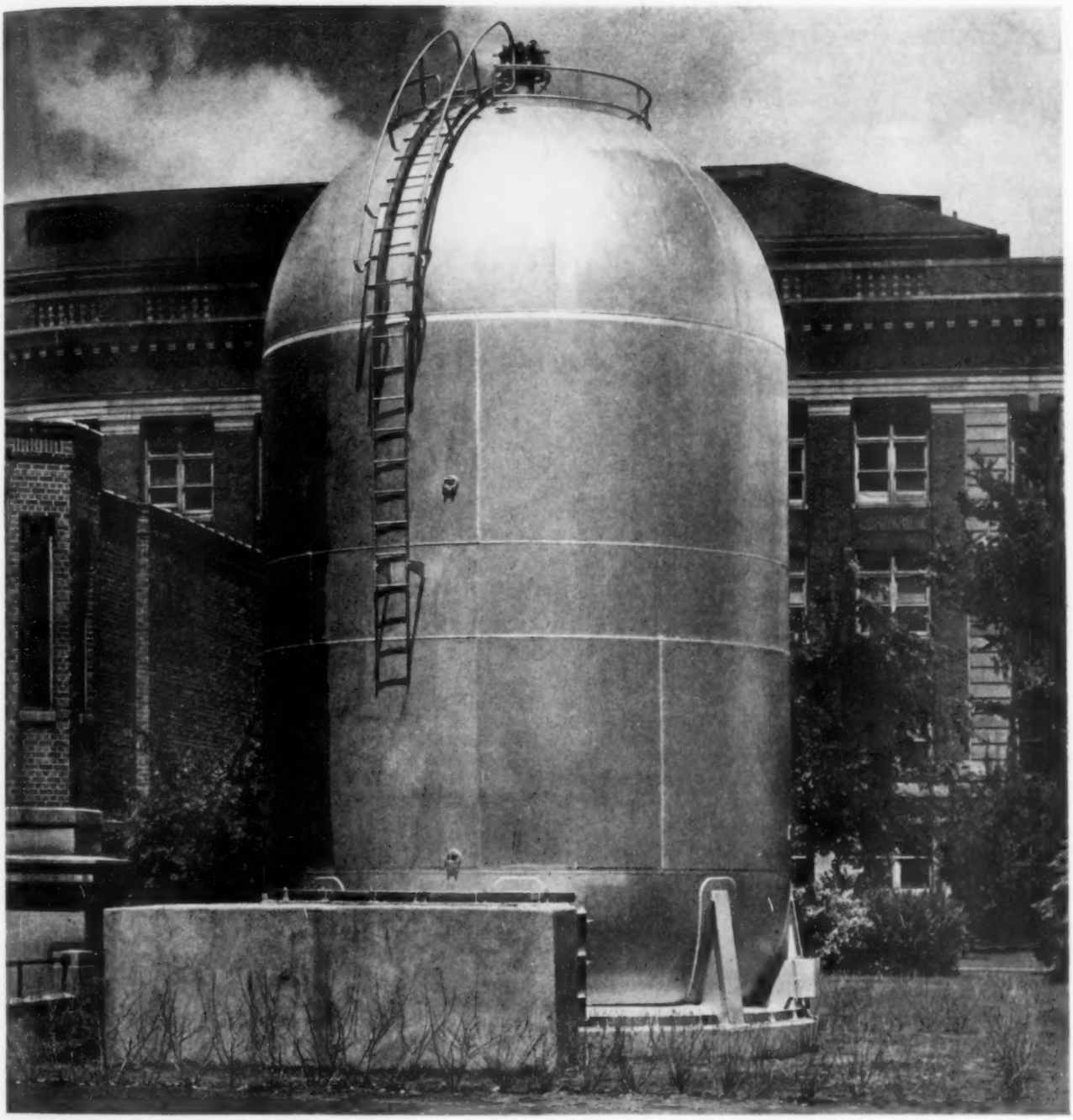
The very interesting possibilities for speeding up defense production and advancing the completion date of armaments and other defense equipment are suggested in the following table of statistics compiled by the Foundation. These statistics show not only the savings in production time, cost and weight but also operating advantages made possible through the greater strength and rigidity of arc-welded construction.

Items covered include both equipment of a military nature and industrial machinery vital in armament production.

The Foundation is sponsoring a $2^1/_2$-year program of industrial study, the object of which is to extend the useful application of welding to the products and works of industry. Awards totaling 446, ranging from $13,700 to $100, and totaling $200,000, will be made after June 1, 1942, the end of the Program.

Examples of Time, Cost and Weights Saved with Arc Welding

Item	Production Advantages	Operating Advantages
9-Ft. Anti-Aircraft Combat Car	Elimination of extra parts and manufacturing operations	Elimination of danger from bolts and rivets being driven into the tank; speed over 100 miles per hour; climbs grades of 50% inclination; as easy to drive as motor car
10,000-Ton Cruiser	Saving of 17% in weight, 3% in cost	Greater maneuverability, operating speed and carrying capacity through reduced deadweight
Two 92-Ft. Tug Boats	20% reduction in construction time; built in only 7 weeks	Increased carrying capacity through elimination of deadweight; elimination of dangers of rivets being driven into hull by high-powered guns
Submarine Mine Layer	Construction time reduced 25%; 15% savings in weight	Permanently leak-proof construction elimination of rivets and their danger of being driven into the interior
610-Ft. Cargo Vessel	Weight reduction 16.2%; cost saving of 25.9%; 20% saving in construction time	Greater safety at sea through increased strength; increased carrying capacity by elimination of deadweight; removal of rivet hazards
Airplane Landing Gear Forks	50% saving in production time; saving of $40 per airplane	Increase of 23.6% in structural strength, thus increasing operating safety
Beaching Gear for Large Aircraft	Cost saving of 31.7%; 20% weight saving; production time saving of 20 to 25%	Easier maneuverability through greatly reduced weight
Field Service Truck Body	A saving of 25% in weight; cost saving of 32%; saving in production time 15 to 25%	Saving in fuel cost by weight reduction; increased service life through a permanently tight construction; reduced cost of maintenance
Trailerized Tank	Approximately 15% weight saving; 25 to 30% saving in production time	Increase of 15% in payload capacity through reduced weight
Locomotive Frame	Cost saving of 47.5%; weight saving 27.5%; saving in production time 30 to 35%	Greater payload capacity; higher operating speed
Locomotive Boiler	10% cost saving; 10% saving in weight	Increased service life; reduced maintenance; high efficiency
Rotary Planing Machine	89% saving in production time; cost saving of approximately 70%	Increased efficiency and service life through greater rigidity of structure



ATOM SMASHERS

. . . of welded construction

Equipment used to smash the atomic structure of various materials is usually housed within a pressure vessel. The compressed air acts as an insulator, reducing current losses from the electrode. The vessel must be smooth on the inside to reduce current losses to the shell. Butt-welding makes both high pressure and smoothness possible, and the exterior of the vessel is pleasing and easily maintained.

CHICAGO BRIDGE & IRON COMPANY

Chicago	2455 Old Colony Bldg.	Birmingham	1507 North 50th Street	Philadelphia	1668-1700 Walnut St. Bldg.
New York	3398-165 Broadway Bldg.	Tulsa	1654 Hunt Bldg.	Boston	1565 Consolidated Gas Bldg.
Cleveland	2282 Rockefeller Bldg.	Houston	2919 Main Street	San Francisco	1097 Rialto Bldg.
Dallas	1489 Liberty Bank Bldg.	Detroit	1556 Lafayette Bldg.	Los Angeles	1455 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM, and GREENVILLE, PA.

COMBINED MEETING BOARD OF DIRECTORS AND EXECUTIVE COMMITTEE

The Board of Directors held an interesting joint meeting with the Executive Committee in the Engineering Societies Building on September 12th.

The Board confirmed the appointments of President Horton on the Permanent Fund Committee announced in the September JOURNAL, the addition of Mr. R. D. Thomas to the Filler Metal Specifications Committee, the appointment of a representative of the U. S. Navy on Minimum Requirements on Instructions for Welding Operators in Trade Schools, and the appointment of Mr. L. H. Johnson to represent the Society on Committee A10 of the A. S. T. M.

The Board voted to refer back to the Section Officers Conference meeting consideration of clarification of the new By-Laws with regard to the returns to the Sections.

In accordance with request received from former officers of the Memphis Section, that Section was discharged. Suggestions were made as to further work which might be done in connection with the Colorado Canton, Louisiana, Omaha, Quad Cities and San Joaquin Sections in order to bring them up to By-Laws requirements.

The possibility of issuing some sort of a certificate to retiring chairmen of Sections was considered and action deferred so that advice might be sought from the Section Officers Conference in Cleveland.

In connection with the second edition of the Welding Handbook, the Editor reported that selection of chapters had been made as well as committee assignments. Work was progressing. It was hoped that an outline of the chapters would be available by November 1st. It is expected that the second edition would be available for distribution late in 1941. The appointment of Dr. D. S. Jacobus as chairman of the Welding Handbook Committee was approved.

Action in regard to the preparation of the Welding History was deferred as it was felt that most of the companies and important persons identified with the welding industry were extremely busy in connection with the armament program. It was felt, however, that the collection of monographs or statements by individuals connected with the welding industry, relating to the history of welding, should be encouraged and these should be kept on file for some future date.

The Committee on Outline of Work made a number of recommendations as to committee appointments.

The possibility of the Society adopting standard procedures for welding certain materials or structures in order to reduce the cost of qualifying processes and procedure was carefully considered. It has been suggested by the Committee on Outline of Work that the Qualification Procedure Committee hold a hearing on this subject in order to provide for general discussion.

Resistance Welding Standards Committee

There has been some discussion between responsible representatives of the Resistance Welding industry and the AMERICAN WELDING SOCIETY, with the idea of improving relationships and expediting progress of standardization in this field. These conferences finally led to a recommendation that the AMERICAN WELDING SOCIETY appoint a fairly large Resistance Welding Standards Committee thoroughly representative of the manufacturers and users. This large committee would, of course, have under it appropriate working subcommittees. It was felt that a large committee of this sort would result in the stimulation of progress, in the correlation of needed activities and, most important, the wide acceptance of any standards promulgated in this field. The Board of Directors approved the recommendation of the Committee on Outline of Work that a Committee on Resistance Standards be appointed.

Reorganization of Storage Tank Committees

At the present time the A. W. S. has four committees concerned with Storage Tanks, namely, Committee on Rules for Field Welding of Storage Tanks, joint Conference Committee with A. P. I. on Welded Oil Storage Tanks, joint Committee with A. W. W. A. on Elevated Water Tanks and Committee on Gravity Tanks, Tank Risers and Towers.

This last-named committee is now being discharged. The Committee on Outline of Work recommended clarification of the situation by only having one committee, namely, Field Welding of Storage Tanks, and that appropriate subcommittees be appointed as conference committees with interested organizations such as the A. P. I., A. W. W. A., A. R. E. A. and others as may be needed. This recommendation was approved.

The American Coordinating Committee on Corrosion

The Society appointed Mr. H. L. Maxwell of the E. I du Pont Company as its representative on the American Coordinating Committee on Corrosion.

A summary of the activities of the AMERICAN WELDING SOCIETY during the past administration year was presented in mimeograph form. A complete report of these activities will be presented by President Horton at the Annual Meeting in Cleveland.

ROBERT A. (BOB) HILL

John A. Roebling's Sons Company of Trenton, New Jersey, announces the appointment of Robert A. (Bob) Hill as Branch Manager of the Southwest Territory, which now includes Texas, Oklahoma, Louisiana, Lower Mississippi and oil-producing sections of New Mexico. He will have charge of sales and local stock of Roebling's complete line, which includes wire rope, welding wire and specialties, electrical wires and cables, cold-rolled flat wire and specialties, and woven wire fabrics.

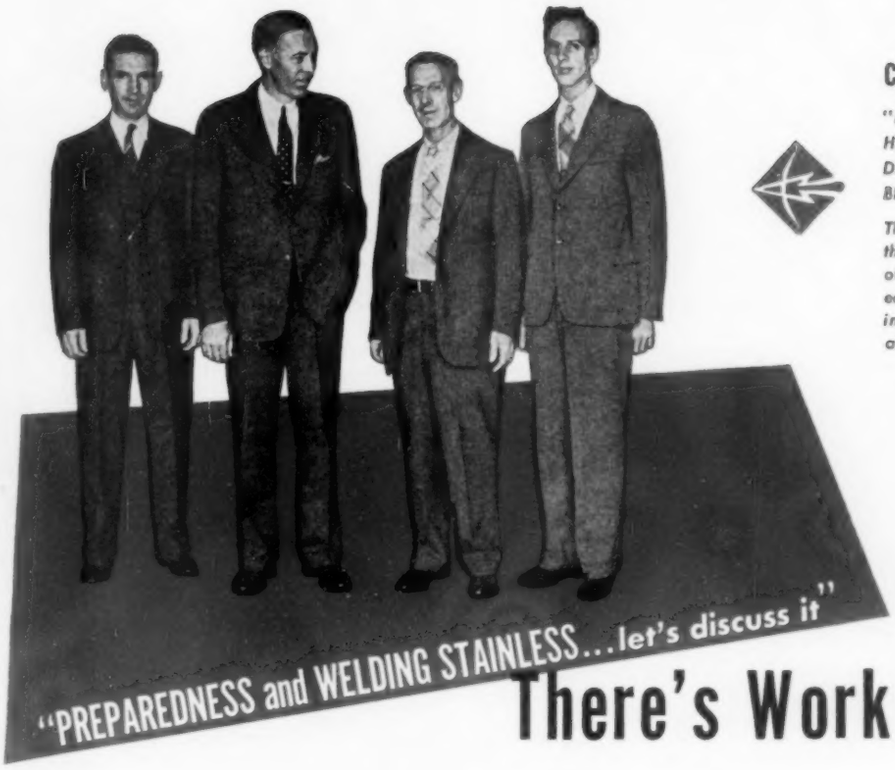
Mr. Hill is a native of the Southwest, worked his own way through Rice Institute, at the same time participating in athletics, and will make his headquarters in Houston. His previous business and technical experience totals nearly twenty years of association with the oil industry. Recently Mid-Continent Manager for Regan Forge and Engineering Company, he was previously Division Manager for Broderick and Bascom Wire Rope Company.

Robert A. Hill

FUEL TANKS

Fuel tanks like this one are produced in numbers by the Angle Products Company, Cleveland, Ohio, for use on road machines. This one was fabricated of 12-gage terne-plate steel with the aid of a 200-ampere, a.-c. arc welder. It has two longitudinal seams, a seam around each end and a seam around the sediment sump at one end. Three baffle plates are welded inside in a transverse position to minimize movement of the fuel. On completion, each tank of this type is tested under a pressure of 25 pounds per square inch.

Photo courtesy General Electric Company
60 Gallon Fuel Tank



AT BOOTH C-27
CLEVELAND—OCTOBER 21-25

"R. D." THOMAS, *President*
HAROLD EWERTZ, *Sales Manager*
DAVE THOMAS, *Metallurgical Engineer*
BILL OSTROM, *Welding Technician*

These men are competent to discuss both the technical and the practical problems of the welding of stainless. Their knowledge is backed by ten years of experience in the manufacture and use of stainless and special alloy electrodes.

There's Work to be Done

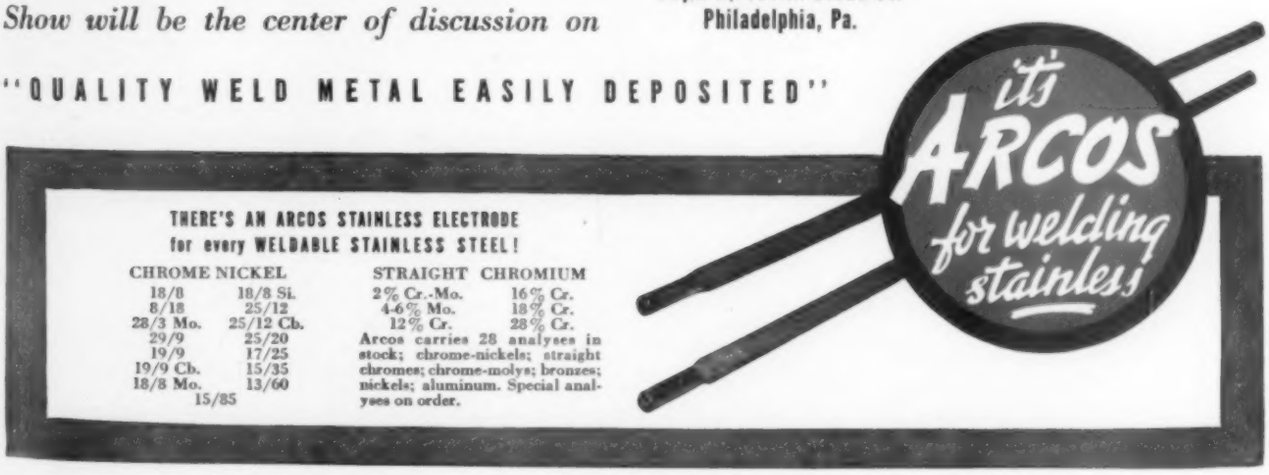
This year the Metal Show is doubly important to you, for it serves not only as an exposition of industrial development, but it also is the meeting place for men with big things to do—and problems.

Among the many "big things to do" in the near future is the fabrication of a vast quantity of stainless steel and alloy equipment requiring welding that must be right the first time. *And the Arcos Booth at the Show will be the center of discussion on stainless welding problems which confront both technical and practical men.*

If welding stainless steel or welding high test special alloys which are not stainless, is in your line, stop in and talk with the men of Arcos—We're not featuring any spectacular fandangles; *we've got our shirt sleeves rolled up for the work to be done—"right the first time" welding of stainless.*

ARCOS CORPORATION
Dept. A, 401 N. Broad St.
Philadelphia, Pa.

"QUALITY WELD METAL EASILY DEPOSITED"



JOURNAL BOX COVERS

Electric arc welding is utilized by the Davis Brake Beam Company, Johnstown, Pa., in fabrication of covers for railroad car journal boxes.

These covers are fabricated of pressed steel (see Fig. 1). To provide rigidity and strength, a small curved stamping (in hand shown in photo, Fig. 2) is arc welded to the hinges.

Fig. 1

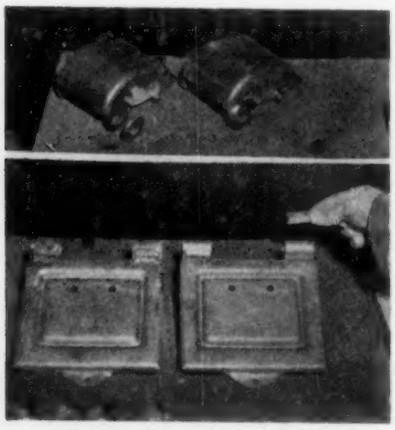


Photo courtesy Lincoln Electric Company
Fig. 2

Figure 2 illustrates another type of cover which is stiffened and given additional strength by washers arc welded in place.

W. C. TILSHER

Warner G. Tilsher has just been appointed Factory Manager of the Taylor-Winfield Corporation.

Mr. Tilsher has been active here and abroad in the development and manufacture of aircraft, streamline trains and other light-weight structures fabricated by resistance welding. He has assisted in the organization and management of several aircraft plants. In 1931 he designed the first airplane completely fabricated by spot welding.

From 1932 to 1934 Mr. Tilsher was in Europe as consultant on special resistance-welding processes developed by the Edward G. Budd Manufacturing Company of Philadelphia, Pa., and since that time he has been active in the United States in this same line.

Mr. Tilsher has recently been connected with the Edward G. Budd Manufacturing Company as Assistant to Works Manager of the Stainless Steel Division, and previous to that he was with Fairchild Aircraft Corporation, American Aeronautical Corporation, and Wright Aeroplane Factory.

W. C. Tilsher

UNITED STATES CIVIL SERVICE COMMISSION

The United States Civil Service Commission announces examinations of interest to persons trained in engineering work, as follows:

Engineering Aid (Aeronautical), five grades, salaries ranging from $1620 to $2600 a year, Army Air Corps, War Department. Applications will be rated as received at the office of the United States Civil Service Commission, Washington, D. C., until June 30, 1941. High-school education or substituted engineering experience (in addition to that needed to satisfy the experience requirements) is required. Applicants must also show subprofessional or professional engineering experience, the amount varying with the grade of the position, in testing, research, design, construction or other engineering activities, a part of it in the field of aeronautical engineering. College study in aeronautical engineering may be substituted for the experience; college study in any other branch of engineering may be substituted for the experience other than that in aeronautical engineering.

Application forms and information may be obtained from the Secretary, Board of U. S. Civil Service Examiners, at any first- or second-class post office, or from the Commission's Washington office.

STEEL ERECTION METHOD

J. H. Williams & Co., Buffalo, New York, are now manufacturing the patented Saxe Welded Connection used in the erection of welded-steel structures. These connections, consisting of an Erection Seat and an Erection Clip, have a wide application and are adaptable to any assembly where structural steel parts must be located and held for welding. The manufacturer states that savings ranging from $3.00 to $5.00 per ton have been effected.

The illustration above shows two steel members securely held in exact position by Saxe Connections and ready for permanent welding. The inset illustration shows the Saxe Clip and Saxe Seat as they are delivered to the steel fabricator for welding in proper position to fabricated steel parts.

The simple hook and eye principle of the Saxe System not only securely locks the steel members in position but its self-aligning action eliminates many hours of costly plumbing up necessary when the usual riveting method is employed. Economy, simplicity and speed are among the advantages claimed for the Saxe method.

Full particulars can be obtained by addressing J. H. Williams & Co., 400 Vulcan St., Buffalo, N. Y.

FRAME FOR ERECTING CRANE

There'll be more than 500 feet of arc-welded joints in this frame for a 15-ton erecting crane when it is completed by the Lewis Welding and Engineering Corporation, Cleveland, Ohio, in whose shop it is shown under construction. This company, with the aid of three a.-c. arc welders, turns out frames such as this at the rate of ten a month. When completed, the frames weigh about 8000 pounds and contain more than 70 pieces of various grades of steel. The cranes themselves have a lifting capacity of 15 tons and are built with booms which vary in length to more than 100 feet.

Photo courtesy General Electric Company
Frames for 15 Ton Erecting Cranes

BLUE PRINT READING

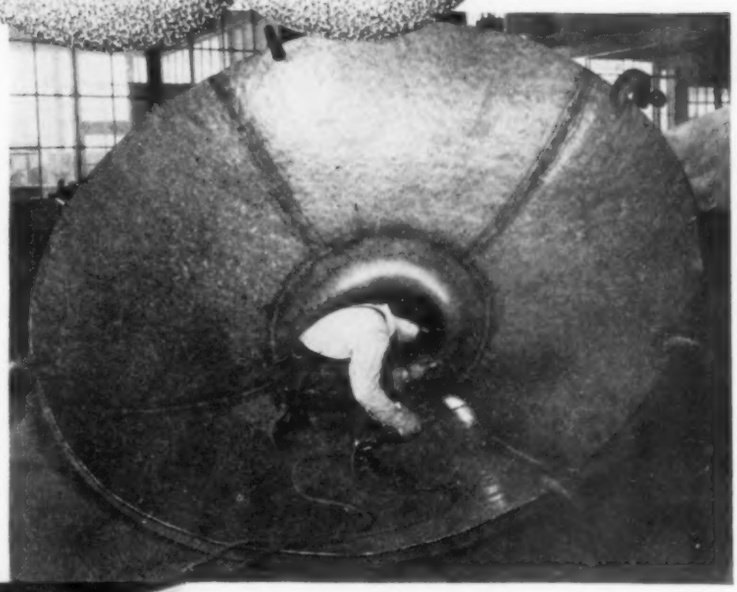
"Simple Blue Print Reading with Special Reference to Welding," published by The Lincoln Electric Co., Cleveland, Ohio. 138 pages, 6 x 9, 164 illustrations, semi-flexible simulated leather cover, gold embossed.

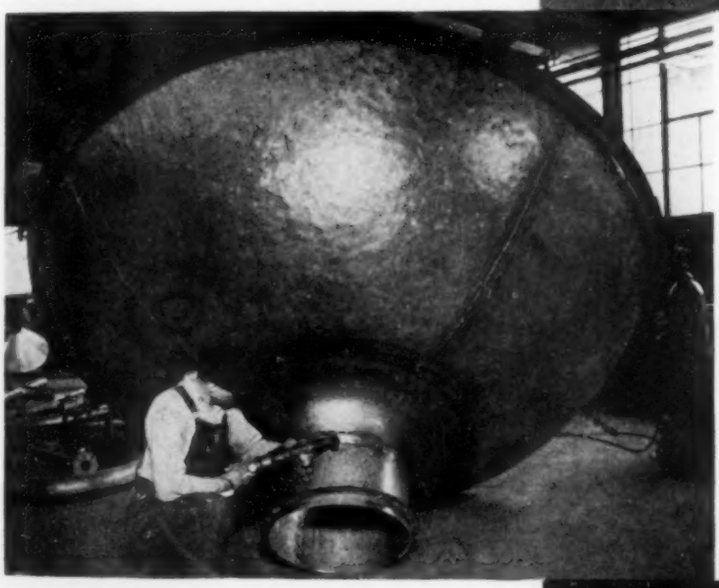
This book affords a basis for study of blue print reading, which, together with practice in the actual reading of drawings,

BREW KETTLE DOME EASY TO WELD IN NICKEL

. . . using #41 Nickel Gas Welding Rod and no flux

Four orange peel sections rough-formed from cold-rolled, soft temper 60″ x 90″ x 0.125″ Nickel sheet make up this 10′ 6″ diameter dome. Radial seams were tack welded and center hole trimmed to take circular throat section . . . which consisted of hand bumped annular part welded to 24″ dia. x 14″ long cylinder. After annular part had been welded to dome, radial seams were welded inside to a depth of ⅔ to ¾ sheet thickness and then outside welded.





(left) Welds capable of being polished both sides, were provided by welding from outside as well as in, thus also minimizing possibility of porosity. Steel angle supporting ring clamped around outer circumference helped maintain shape during handling and welding. All welding done with 3/32″ dia. *#41 Nickel Gas Welding Rod*, using slightly reducing oxy-acetylene flame, and no flux.

On completion of all welding, inside and outside welds were rough ground, leaving a slight reinforcement to permit cold working of weld metal by hand hammering. Entire dome was then planished with a spring hammer. Polishing was started with a 120 grit wheel, followed by 180, and final satin finish applied by Tampico wheel.

Monel*, Nickel and Inconel* are readily welded, with welds as solid, strong, and corrosion resistant as the parent metal. Bulletin T-2, "Welding, Brazing and Soft Soldering Monel, Nickel and Inconel" gives full information. Write for revised and enlarged June 1940 edition. Address:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York, N. Y.

*"Monel" and other trade-marks which have an asterisk associated with them are trade-marks of The International Nickel Company, Inc.

will guide the student to proficiency in this important subject. While the book has been compiled and published primarily for welders, it contains information of value for anyone concerned with mechanical construction. With the help of the book, the student can learn with a few hours' spare-time study what it would take many months to pick up in the ordinary course of every-day work. It will enable welders, mechanics and others to answer questions for themselves, thus saving the time of the welding supervisor or foreman.

The text is concisely written in simple, practical language for ready understanding. Drawings, made in clear, solid black lines and with extra-large lettering, assure easy legibility.

"Simple Blue Print Reading" may be obtained directly from The Lincoln Electric Company or through any of its dealers or representatives, or through any recognized book dealer. Price is 50c per copy, postpaid anywhere in the U. S. A., 75c elsewhere.

ARC-WELDING STRINGERS FOR HONEYMOON BRIDGE AT NIAGARA FALLS

Replacing this famous bridge that was destroyed by ice a couple of years ago, stringers are being welded together for

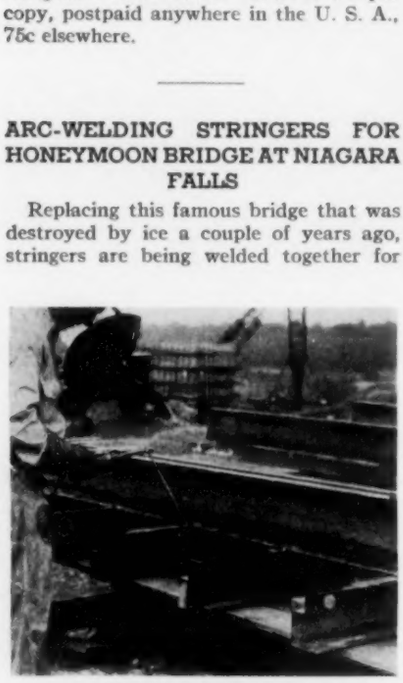


Photo courtesy Hobart Brothers Company

tying the bridge together, across Niagara River. The work is being done by 300-ampere gasoline engine portable welders with $^3/_{16}$-rod.

WELDING HANDBOOK

Case School of Applied Science is badly in need of a supply of the Welding Handbooks for use in connection with their courses. They have offered to pay $5.00 each for slightly used Welding Handbooks in good condition. Prospective sellers should communicate with Prof. E. B. CARSON, Case School of Applied Science, Euclid and Adelbert Rd., Cleveland, Ohio.

NEW FEET ON TAMPER DRUMS

Accompanying illustrations show an advantageous use of arc welding in repair of earth tampers by Pacific Constructors, Inc., at Shasta Dam.

The tamper drums, 5 feet in length by 58-inch diameter, each contain 108 feet

Fig. 1

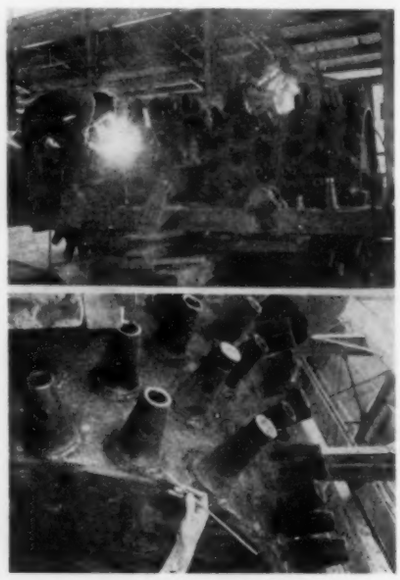


Photo courtesy Lincoln Electric Company
Fig. 2

which are steel castings. Repairs are accomplished by cutting off the old feet with a cutting torch, smoothing the surface with a chipping hammer and arc welding the new feet in place with two passes, utilizing $^3/_{16}$-inch shield arc.

Arc welding new feet to a tamper drum can be seen in Fig. 1. Figure 2 is a close-up showing the welds.

ARC-WELDED LIGHT TOWERS FOR CHICAGO PLAYGROUNDS

This all-welded floodlight tower is being fabricated in the shop of the Mississippi Valley Structural Steel Company with the aid of a portable arc welder. The all-welded construction of this tower means a

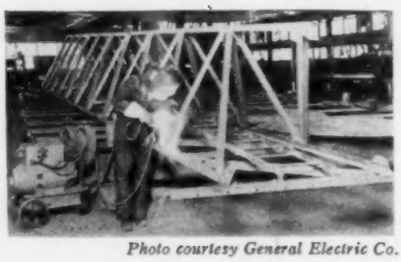


Photo courtesy General Electric Co.

saving of both time and money for the fabricating company, which, incidentally, is supplying 64- and 80-foot towers like this for Chicago playgrounds.

UNITED STATES CIVIL SERVICE EXAMINATIONS

Senior Engineer, $4600 a year.
Engineer, $3800 a year.
Associate Engineer, $3200 a year.
Assistant Engineer, $2600 a year.

Optional Branches: (1) Electrical, (2) Heating and Ventilating, (3) Materials, (4) Mechanical, (5) Mining, (6) Radio, (7) Structural, (8) Telegraph, (9) Telephone, (10) Welding.

Announcement No. 83 is hereby amended to extend the closing dates for receipt of applications. *Applications will be rated as received at the Washington office of the U. S. Civil Service Commission until June 30, 1941,* and certification made as the needs of the service require; except that if sufficient eligibles are obtained, the receipt of applications may be closed before this date, in which case due notice will be given. A subsequent application for this position will not be accepted from any applicant within three months from the date of receipt of his preceding application under this announcement.

When an applicant who has been rated eligible in this examination for any of the grades listed above files a subsequent application, but is found ineligible for a higher grade than that for which he has been rated, his application will be canceled and no additional rating will be assigned him in the grade for which he is already eligible.

There is an urgent need for persons qualified as Heating and Ventilating Engineers, Material Engineers, Radio Engineers, and Welding Engineers.

RAPID BUILDING CONSTRUCTION OF ARC-WELDED STEEL FOR CHEMICAL COMPANY

The accompanying illustration shows the first of five all-arc-welded steel buildings being erected for Mathieson Alkali, Niagara Falls, New York, by the Kenmore Contracting Company. The city code is just being changed to allow this new type of construction.

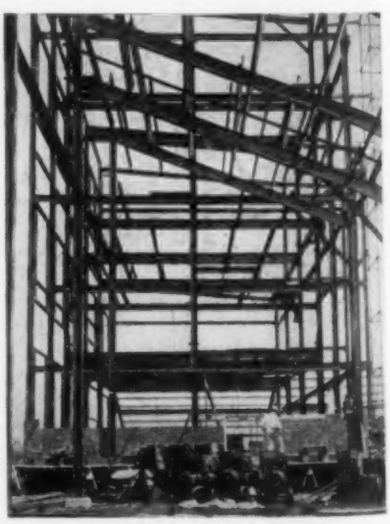


Photo courtesy Hobart Brothers Company

SPOT WELDS WITHOUT EQUAL..!

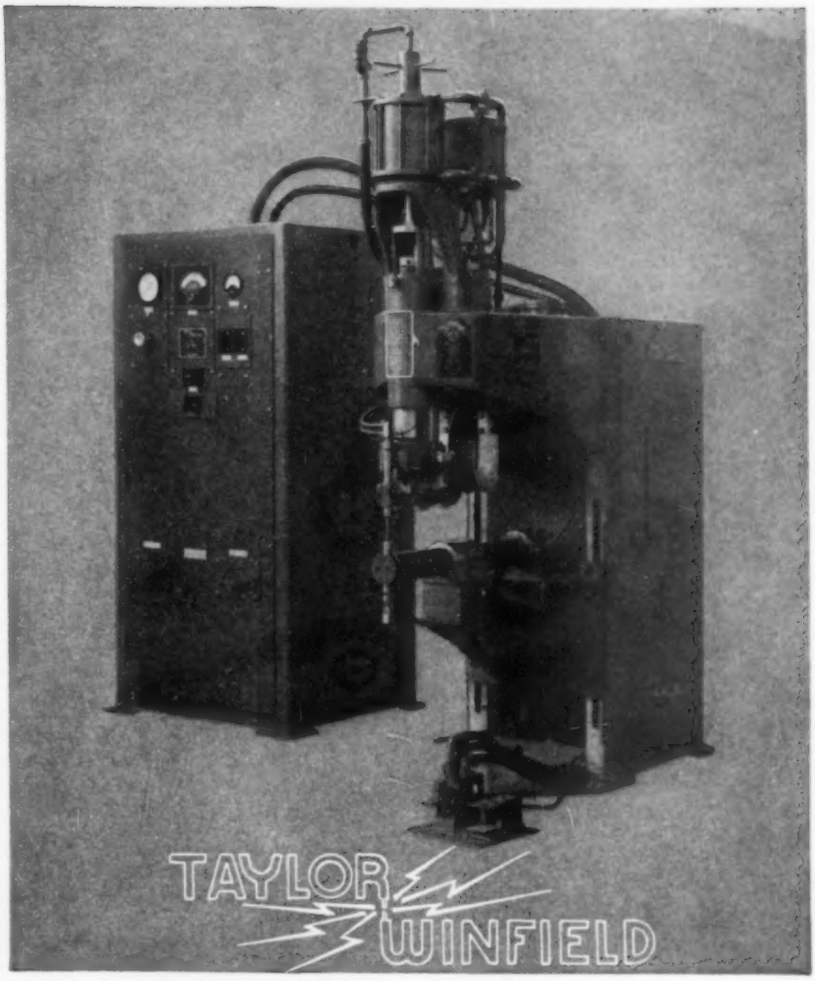
Taylor-Winfield again presents industry with another and greatly perfected spot-welder—an exclusive product of its research laboratory, designed and built under *one* responsibility.

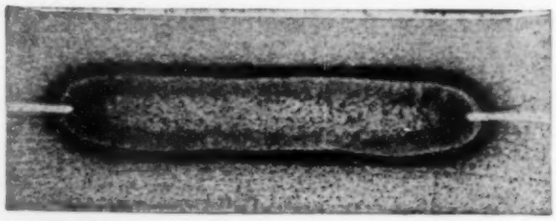
It's the NEW HI-WAVE Welder combining these salient features:

- **Three phase operation at high power factor**
- **Low power demand eliminating expensive installation**
- **Simplified controls readily accessible**
- **Weld structure entirely free from cracks or other faults**
- **Uniform results**
- **High production speed**
- **Long electrode life**

That you may personally inspect the quality of the welds produced by this HI-WAVE Welder, a unit will be in operation at the Metal Show—Booth B-36.

Other demonstrating units are in operation at 2020 Santa Fe Avenue, Los Angeles and at the factory, Warren, Ohio. Complete details in Bulletin No. 1405.





Photomacrograph of HI-WAVE Weld in two pieces of 0.064" thick 24 ST Alclad. Magnification 10 diameters.

HI-WAVE

WELDERS

The TAYLOR WINFIELD Corporation

WARREN, OHIO, U.S.A.

MANUFACTURERS OF
ELECTRIC, BUTT
SPOT AND SEAM
WELDERS

TAYLOR-WINFIELD Welders are manufactured and sold in Canada by COMMONWEALTH ELECTRIC CORPORATION, LTD., Welland, Toronto and Montreal; and in Europe by AB. ASEA SVETSMASKINER, Stockholm, Sweden.

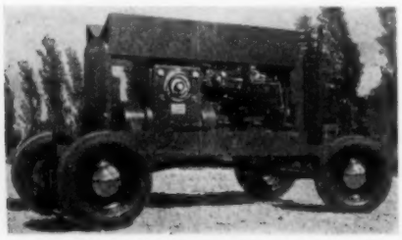
The Denton & Anderson Company—Cleveland, Chicago, Detroit
Other Representatives in principal cities of the U. S.

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

NEW HEAVY-DUTY GAS DRIVE ARC WELDER

To meet the demand for a rugged, heavy-duty gasoline engine portable arc welder that can "go places in a hurry"—and do a heavy job well—a new Hobart welder is now being offered.



Heavy-duty chassis, sturdy portable mounting and trailing hitch open up new speeds for getting to the job over smooth highways or rough terrain, with a minimum of delay or difficulty.

Six and eight cylinder, counter-balanced industrial type motors, silent in operation and free from vibration is directly connected to the Hobart Simplified Arc Welder. Remote control is also available on this outfit at no extra cost.

A.-C. ARC WELDER WITH HIGH POWER-FACTOR

The General Electric Company, Schenectady, N. Y., has announced a new line of 500-ampere A.-C. arc welders offering advantages in performance and economy resulting from mechanical improvements and a new electrical design which incorporates power-factor correction.

This built-in feature makes possible a greatly increased power-factor, which practically eliminates the useless lagging current drawn by conventional designs. Hence, smaller primary cable, line switches and fuses can be used.

When operated below half load, this welder provides leading reactive kva. for improvement of the shop power-factor; and when operated at no load, there are 19.5 kva. available for this purpose.

Other advantages offered by this new G.-E. arc welder include finger-tip adjustment by means of an easily turned current-changing crank; a large, easily read current indicator extending up the side of the transformer case; protected output terminals accessible through holes in the insulating panel; and fan-forced ventilation, providing cool, dependable operation even at high currents or high-duty cycles. This refinement in design permits a reduction in size, weight and floor-space requirements. Hence, the new welder is less than four feet in height, only 21 inches in diameter and has a net weight of 600 pounds.

The only maintenance required is lubrication of the fan and current-adjuster every 12 to 18 months. The case, however, is easily removable so that inspection can be made, if desired.

WELDING GALVANIZED SHEETS

Patents on an entirely new process of welding galvanized sheets and structural elements, regardless of size, so that the joints are left in a rust-proof condition, were granted to The Artkraft Sign Company on August 10th, Lima, O., according to Toulmin & Toulmin, Patent Attorneys, Dayton, Ohio.

Heretofore, it has been impossible to weld without burning off the galvanizing, thereby leaving joints subject to rust.

The discovery was the result of a search for a method of producing a rust-proof and vibrationless sign frame, and is now used in the manufacture of Artkraft products. Inquiries are invited and licensing arrangements are being made with manufacturers in all fields where rust-proof products are desirable.

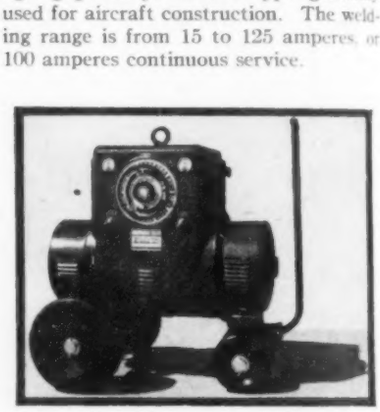
The Research Department of The Artkraft Sign Company states that the new process, named "Galv-Weld," consists of regalvanizing at the time of welding. The resulting joint is more rust-proof than the balance of the galvanized elements because the regalvanizing is done while the steel is cherry red, thereby making a relatively deep penetration of the galvanizing material into the steel, whereas the original galvanizing was done by "hot-dip" material on cold steel.

Heretofore large structures could be entirely galvanized only by immersing in "hot-dip" after assembling. This has proved too awkward, expensive and impractical for wide use, while the bolting together of galvanized elements has been unsatisfactory as it results in a much weaker structure.

"AIRCRAFT SPECIAL"

The Hobart Brothers Company, Troy, Ohio, announces development of a new Motor-Generator type of D.C. Arc Welder, specially designed to meet modern requirements of production welding in aircraft factories.

This new welder provides high striking voltage that makes possible the exceptionally "hot start" required in welding light-gage alloys of the type generally used for aircraft construction. The welding range is from 15 to 125 amperes, or 100 amperes continuous service.



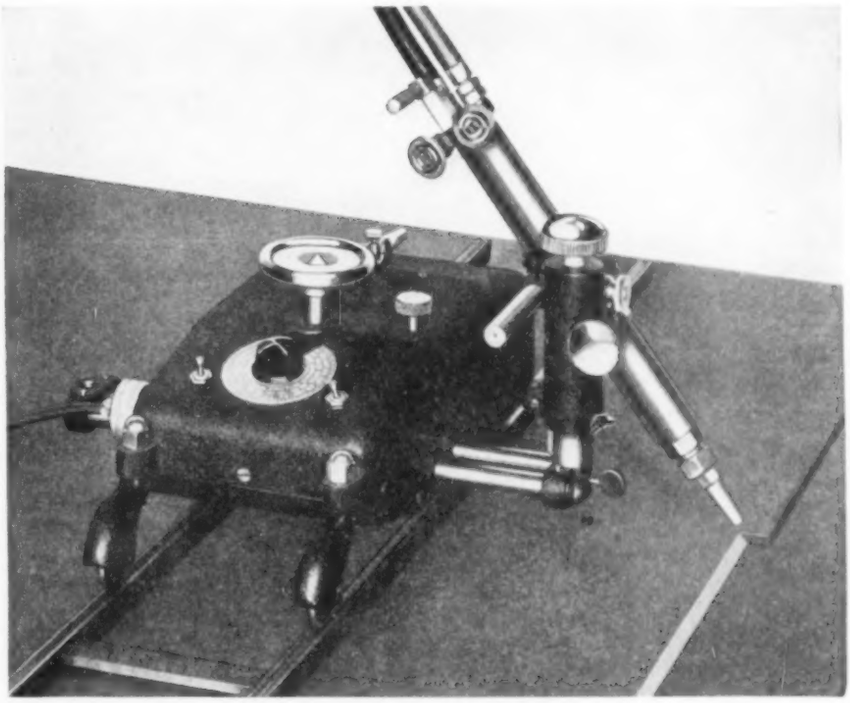
Although known as the "Aircraft Special," this new Hobart arc welder is also available for other applications of light-gage welding and has already received favorable comment in connection with certain operations involved in welding galvanized steel in shipyard production work.

SPOT WELDER

The Eisler Engineering Co. of 740-770 So. 13th St., Newark, New Jersey, has placed on the market a long-horn spot welder No. 250-AA for deep sheet metal work. The new feature on this machine is that both upper and lower horns can be lengthened or shortened to meet the requirements of the size and type of work. The new horn adjustment makes it possible to weld light and heavy work and deep metal parts. The markings on the horn represent the kva. ratings—when the horn is placed on the 25-kva. mark it represents 25 kva., etc. The model illustrated is a 25- to 50-kva. air-operated welder.

Announcing

THE NEW MODEL "K"



SPECIFICATIONS

Speed Range 3" to 60" per min., Forward or Reverse; Free Wheeling; Cuts Circles 1" to 86" in diameter; Bevels, any Angle; 2-Torch Mounting; Motor 110 volt AC or DC; Weight 45 lbs; 2 Large Hardened Drive Wheels; 2 Swivel Follower Wheels; 1-Point Oiling System; Durable Black Crackle and Chromium Finish; Cutting Capacity Standard Torch 10"; Special Attachments for wide variety unusual applications.

PORTABLE CUTTING MACHINE

For 35 years HARRIS Torches, Regulators and Acetylene Generators have been serving tens of thousands of plants all over the world. This world-wide use has been due to Timely and Efficient Designing. HARRIS now announces a new advanced Portable Model "K" Motor-Driven Gas Cutting Machine. It cuts straight lines of any length with square or beveled edges; 1" to 86" diameter circles. Exceptional speed range from 3" to 60" per minute, forward or reverse. *Instant Stop* feature (no over-run) for cutting sharp angles, and a Tracing feature for irregular forms. Many different Torches are available for this Machine to efficiently use any Fuel Gas in combination with Oxygen.

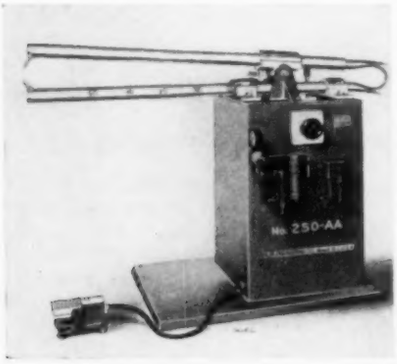
The Model "K" opens new manufacturing fields and enables shops to expand their services and profitably handle work heretofore out of their equipment range. Illustrated descriptive folder will gladly be forwarded upon request.

The HARRIS CALORIFIC CO.

DISTRIBUTORS IN ALL PRINCIPAL CITIES

5501 CASS AVENUE N. W. CLEVELAND OHIO

The spot welders are made with many different styles of electrodes, and in this case the cooling water goes through the entire horn. Available in three sizes:



5 to 25 kva., 25 to 50 kva. and 40 to 75 kva. with horn lengths of 30, 36 or 40 inches. Various types of fixtures and attachments are supplied when required for a particular problem.

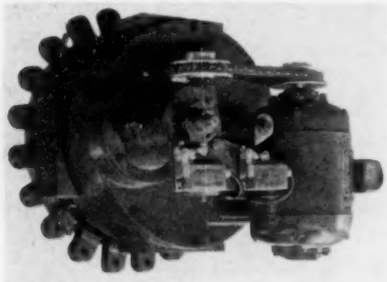
ROTARY TYPE ULTRASPEED SWITCH

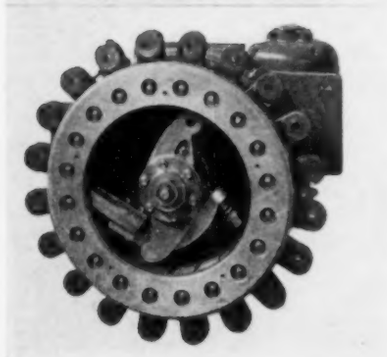
Below are shown top and bottom views of a new design of ultraspeed switch recently developed by Taylor-Winfield, Warren, Ohio.

The top view of this mechanism shows the driving motor, speed reducer and cam-operated limit switches. One of these switches is used to stop the motor after one complete cycle of operation, while the other limit switch is used to initiate the welding timer. The bottom view shows the commutator and brush rigging.

In operation, the motor drives the brush-holder rigging through a worm-gear reducer and Geneva motion, thus indexing the brush from one segment to another. The weld is made while the brush is stationary on the commutator section, thus eliminating the transmission of heavy welding currents while the brush is in motion.

Another advantage of this design is that for each operation of the unit, it returns itself to its starting position by virtue of its rotary motion, thereby eliminating reversing motor control which is necessary on straight line action devices.





ANGLE METER

The Angle Meter was developed to furnish a means by which the man on the job can quickly lay out, directly on the pipe or flat material, any angle cut from 0° to 90°.

Using a method of measuring in both directions from a center line, it requires only 4 measurements to mark a pipe or stretch out in 16 different points on the circumference. All measurements are taken from the right-hand side of the pointer to the zero line.

Where the lines are not calibrated, a rule is placed with the end against right-hand side of pointer and the measurement read at the zero line. The rule should be held parallel to the nearest existing horizontal line.

The Angle Meter is distributed by Interstate Sales Co., 1123 Broadway, New York City.

TUNGSTEN ELECTRICAL CONTACTS

It is announced that the Metroloy Company, Inc., 57 East Alpine Street, Newark, New Jersey, are now manufacturing electrical contact points, made from highly fused pure tungsten metal—assuring uniformity in grain structure, eliminating any excessive oxidation or pitting during operation periods.

The purity of this metal avoids film coatings from adhering to contact surfaces during the time when apparatus is not operating or at shut-down intervals.

It is further found that due to elimination of these difficulties the electrical contact surface resistance is maintained at a minimum and that long service operation is assured.

WELDING HOSE—TWO LINES OF WELDING HOSE MOLDED INTO ONE!

The ease of handling—the greater safety—the faster operation—and the longer life of Hewitt patented Twin-weld Welding Hose all mean lower cost on every welding job. Twin-weld Hose, a "double-barreled" unit, is made up of two lines of highest quality, cord-reinforced welding hose molded side by side in one complete unit, eliminating entirely the need for makeshift taping of individual lines to prevent the hazardous tangling and sprawling of separate units. The operator no longer needs to tug and haul to reach his job. He can change position with complete freedom—and it's a simple matter to coil up the hose for moving equipment from one location to another. Hewitt Rubber Corporation, Buffalo, N. Y.

RESISTANCE "FORGE-WELDING"

"Forge-Welding" is a new process of heavy duty electric resistance welding for spot welding heavy steel and iron sections heretofore considered impossible to weld with conventional equipment. With it, such work can be handled almost as easily and rapidly as spot welding sheet metal.

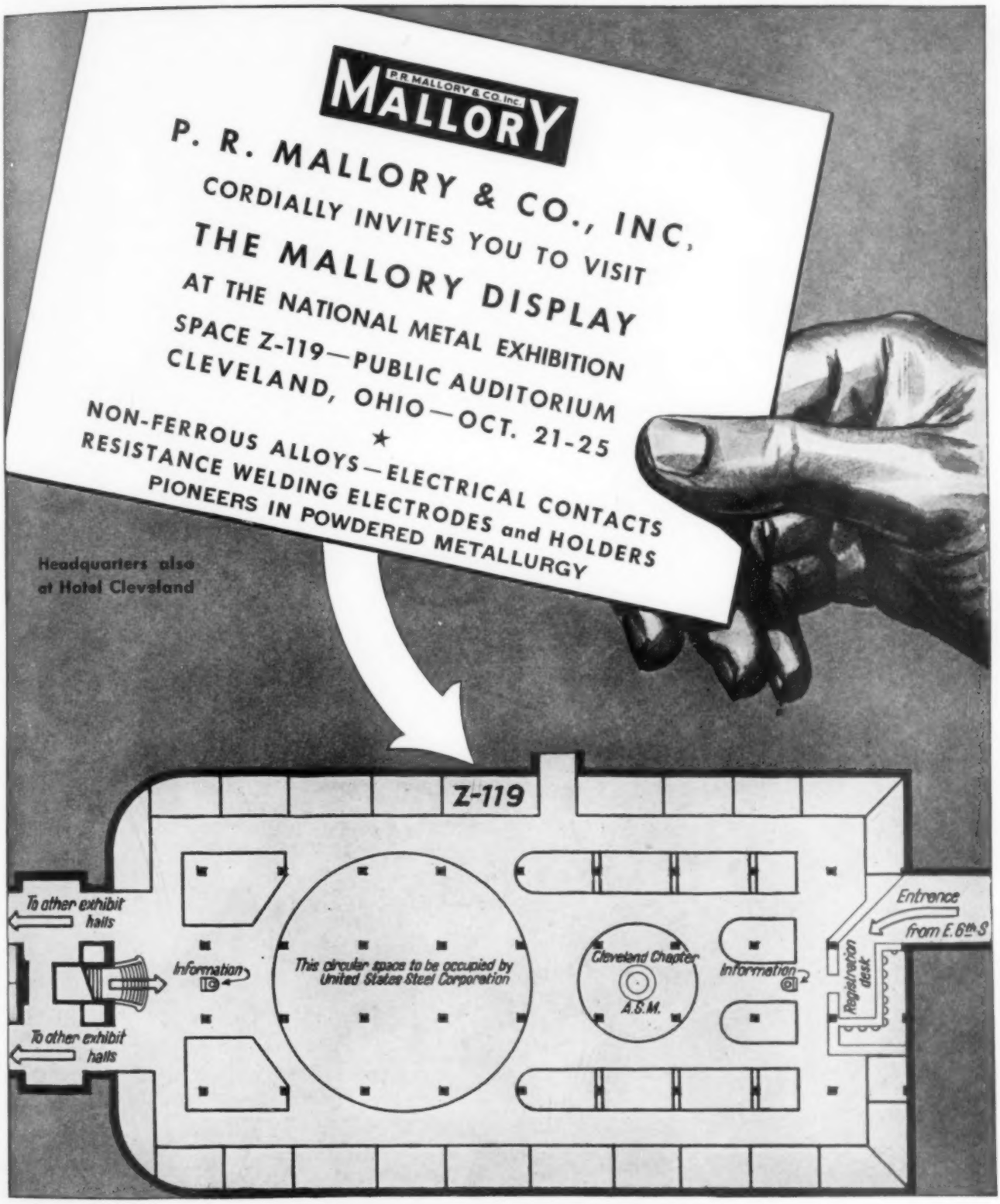
The process as announced by Progressive Welder Company, 3034 East Outer Drive, Detroit, Michigan, has the promise of opening up new fields for resistance welding in the fabrication of structural steel assembly. Even the fabrication of heavy sections for defense equipment which are expected to come within its capacities may prove to be of tremendous importance in the defense program.

In principle the process harks back to—and derives its name from—one of the earliest forms of welding: heating, forging, reheating, reforging, etc. In comparison, however, the new process is extremely rapid.

Although developed over a year ago, announcement had been with held pending completion of field tests on various types and thickness of metals under actual service conditions.

Typical of work now being handled is: welding of two pieces of $^3/_8$ inch stock to a 1-inch section; welding together two 1-inch sections, etc.

Resistance Forge-Welding consists of first applying pressure to the work, then interrupted current, and finally superimposing a hammering action on the electrode. Under high pressure and with sufficient heat, the surfaces of work are brought into such intimate contact that when additional "impact-pressure" and intermittent heat are applied a forged weld of superior quality is obtained.

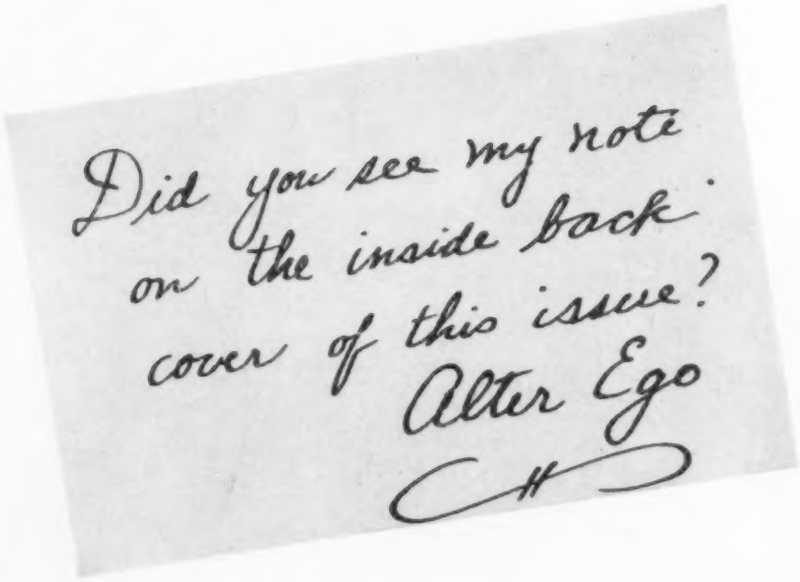


P. R. MALLORY & CO., Inc.

P.R. MALLORY & CO. Inc.
MALLORY

INDIANAPOLIS, INDIANA
Cable Address—PELMALLO

NON-FERROUS ALLOYS and ELECTRICAL CONTACTS


Did you see my note
on the inside back
cover of this issue?
Alter Ego

Long before the present emergency, plants all over the country, interested in metal joining found that Sil-Fos and Easy-Flo provided reliable joints in fast time at low cost. Large quantities are now regularly used in the automotive, aviation, electrical, refrigeration, air-conditioning and coppersmithing industries and for general manufacturing. These alloys are included in Navy and Federal Specifications. To manufacturers now interested in faster production without sacrificing reliability, Sil-Fos and Easy-Flo offer an opportunity that is well worth investigating.

SIL-FOS AND EASY-FLO

BRAZING ALLOYS MEET TODAY'S NEED FOR *SPEED* WITH *RELIABILITY* IN METAL JOINING

***They're* FAST** – Low working temperatures (Sil-Fos 1300 Deg. F. and Easy-Flo 1175 Deg. F.) plus exceptional fluidity make the brazing action so fast that a single operator often can do as much as two or more using other methods.

***They're* EASY TO USE** – Any operator can catch on to the Sil-Fos and Easy-Flo brazing technique in a few minutes. They fit in perfectly on many mass production set-ups.

***They're* RELIABLE** – Finished joints give full metal strength and are ductile and dependable where shock and vibration are severe. Millions of joints are made every year in spots where permanence ranks first in importance.

***They're* ECONOMICAL** – In your plant low brazing temperatures, instant penetration, thin films of alloy, little or no finishing, will mean savings in time, gases and materials. The cost per joint is surprisingly low.

TRY THEM ON YOUR WORK – Try Sil-Fos on non-ferrous metals and Easy-Flo on iron, steel, stainless steel, Monel, Everdur, or other ferrous or non-ferrous alloys. Easy-Flo is considered by many to be the most reliable way of joining *dissimilar* metals. For full details mail the coupon below — today.

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We are interested in getting faster, better production on our metal joining work and accept your offer to assist as checked below.

- ☐ Send us the SIL-FOS and EASY-FLO Bulletins.
- ☐ Have a field engineer call and check our metal joining operations.
- ☐ Have a field engineer call and demonstrate SIL-FOS and EASY-FLO.

NAME ..... TITLE .....

COMPANY .....

STREET ..... CITY & STATE .....

» » » SECTION ACTIVITIES « « «

CLEVELAND

The Cleveland Section has scheduled the following series of meetings. All six regular sessions will be dinner meetings at the Mid Day Club atop the Union Commerce Building.

October 9th, 1940—"Welding in National Defense," J. F. Jenks, Col. Ordnance Dept., U. S. Army, Army Munitions Bldg., Washington, D. C.

November 13, 1940—"Resistance Welding," John J. MacKinney, Welding Engineer, E. G. Budd Mfg. Co., Philadelphia, Pa.

December 11, 1940—"Welding in the Shipbuilding Industry," David Arnott, V.-P. and Chief Surveyor, American Bureau of Shipping, 24 Old Slip, New York, N. Y.

January 1941—A fun social meeting—date and details later.

February 12, 1941—"Welding of Stainless and Alloy Steels," H. C. Esgar, Sales Engineer, Carnegie Illinois Steel Corp., Pittsburgh, Pa.

March 12, 1941—"Welding in the Building Industry," J. H. Frankland, C.E., American Institute of Steel Construction, Inc., 200 Madison Ave., New York.

April 9, 1941—Forum—This will be sort of an "Information Please" question and answer meeting and we will select a number of recognized experts to answer questions from the floor. The details of this meeting will be arranged later.

May 9, 1941—Annual Symposium—Statler Hotel. Three or four speakers and a dinner. Details later.

The educational course will be held during January and consists of a series of five or six meetings at Case School under the leadership of the Educational Committee Chairman Professor Gordon B. Carson.

LOS ANGELES

The first meeting of the new season of the Los Angeles Section was held on Thursday, September 19th. Mr. H. C. Boardman, Past-President of the A. W. S. and Research Engineer for the Chicago Bridge and Iron Company, spoke on the subject, "Field Welding of Storage Tanks." Mr. Boardman is aptly qualified to talk on this subject because of the many practical applications with which he has recently been associated and considerable interest was aroused at the meeting. Another speaker at the meeting was Major A. R. Baird, U. S. Army Ordnance Corps, who spoke on "Industrial Preparedness." Major Baird's talk particularly concerned industry in Southern California.

At a luncheon meeting it was tentatively decided, among other things, that the Los Angeles Section would sponsor lectures and papers to make up a program for Western Metals Congress and the Section will have its own technical sessions. A committee will be appointed to take care of this matter.

MILWAUKEE

Newly elected officers for the Milwaukee Section are as follows: *Chairman*, R. E. Boeck, Worden Allen Co.; *Vice-Chairman*, J. J. Chyle, A. O. Smith Corp.; *Sec.-Treas.*, G. F. Meyer, Machinery and Welder Co. *Directors for 2 years:* E. C. Brekelbaum, H. E. Bailie, L. J. Kein. *Directors for 1 year to fill unexpired terms:* H. O. Quartz, Paul Corp.

At the September meeting held on the 20th Mr. Paul Coddington, President of Lakeside Bridge & Steel Co., gave a very interesting after-dinner talk, "On Wings to the Pacific." Mr. R. F. Flood, Service Engineer of The Linde Air Products Co., presented a welding address on "Flame Hardening."

The next meeting of the Section will be held on Friday, October 18th. Mr. T. N. Armstrong, International Nickel Co., is scheduled to speak on "Welding of Nickel Steels."

NEW YORK

The New York Section plans to start its 1940–41 Season of activities with a meeting at the Engineering Societies Building on October 8th. This meeting will be a Question and Answer Program—the questions to be submitted by anyone in attendance either prepared or otherwise, and answered by the Board of Experts who have agreed to serve.

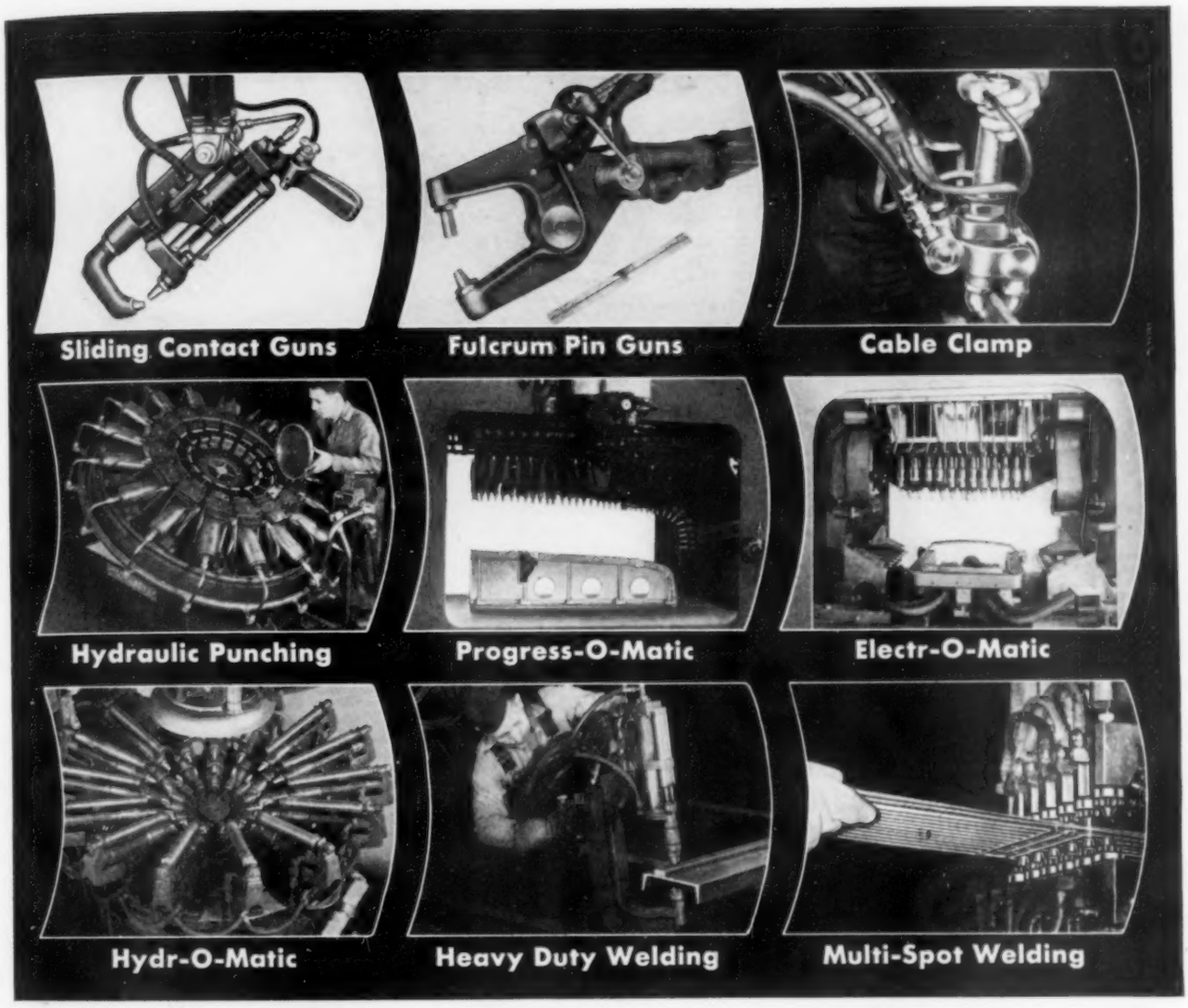
The second meeting of the year will be on November 12th. The chairman of this meeting will be Mr. John Haydock, Managing Editor of the *American Machinist*. This meeting is to be held jointly with the New York Section of the A. S. M. E. Mr. W. Roy Widdoes, General Manager, By-Products Steel Company, of Coatesville, Pennsylvania, and Mr. J. H. Cooper, Welding Engineer of the Taylor Winfield Corporation, Warren, Ohio, will speak on subjects concerning application of welding to machinery fabrication.

Although the program for the year is not entirely completed, dates for other meetings have been set as follows: October 8, 1940; November 12, 1940 (joint meeting with A. S. M. E.); December 10, 1940; January 14, 1941; February 11, 1941; March 11, 1941; April 8, 1941; May 6, 1941.

NORTHERN NEW JERSEY

Favored by a full day of ideal autumn weather more than a hundred members

New Jersey Section on Their First Outing



Increase Sheet Metal Assembly Speeds
With these New Developments

Manufacturers who thought they employed the fastest methods for handling big multi-spot assemblies have had to revise their ideas of speed—upwards. Developments such as Progressive's Hydr-O-Matic, Progress-O-Matic, and Electr-O-Matic, together with Progressive's Hydraulic Punching Equipment, have given their programs a tremendous impetus.

Manufacturers of smaller assemblies who thought that "production welding and punching is not for us" have suddenly found themselves moved up into the mass production class with low cost portable gun welder units and individual unit punching equipment.

All have saved money. All have turned out a better product and have made more profit.

Some of Progressive's recently developed equipment which they have used is shown here. More of it together with the revolutionary Resistance Forge-Welding which welds heavier work than ever welded before will be on display at the METAL EXPOSITION in Cleveland.

Find out what it will do for you!

Information concerning your problem and the best means of doing it better, cheaper and for a bigger profit is yours for the asking.

Ask Progressive how it can be done.

PROGRESSIVE WELDER CO.

3034 EAST OUTER DRIVE, DETROIT

and guests of the AMERICAN WELDING SOCIETY, Northern New Jersey Section, gathered at Angele's Grove, Unionville, N. J., Sept. 7th, for their first summer outing. The Outing Committee, under the able direction of Dr. G. C. Holder, had arranged for a day of complete informality. Facilities and equipment were provided for soft-ball, soccer, horseshoe pitching and shuffleboard with no planned program to interfere with the continuous enjoyment of any game. A varied and toothsome buffet lunch was likewise served continuously from noon until sunset, with cold beer on tap and on a "come and get it" basis.

Chairman F. C. Fyke and George Blind set a hot pace at horseshoe pitching early in the day and in short order more stakes were set up. It rained horseshoes in that corner of the grove for the rest of the day. A soft-ball game raged for several hours without loss of a single umpire. A score of 21 to 5 was announced, but the reporter could not determine whether this was for the ball game or one of the horseshoe contests. It really doesn't matter, because the outing was voted a complete success and it served its purpose of giving members of the Northern New Jersey Section a fine chance to get well acquainted before the beginning of the formal programs.

The regular meeting of the Section was held on September 17th. Mr. Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corp., addressed the meeting on "What Is a Weld?"

A motion picture, "The Welding Arc," was presented through the courtesy of the General Electric Company.

NORTHWEST

George T. Horton, our national president, and president of the Chicago Bridge & Iron Company, opened the 1940–41 season with an interesting address on "Welded Structures," illustrated by lantern slides, at the St. Anthony Commercial Club Tuesday, September 10th.

Mr. Horton drew upon his long experience in the welding field for comparisons, showing the great advances made in technique and applications in welding. He said that during the last war very little welding was permitted, while at the present time there are many welded ships under construction. The savings to be had from welding by the redesign of machinery is very great in the structural field and in shipbuilding. He emphasized that welded design was different from riveted design and that if the latter is applied to welding the cost will be excessive.

Another interesting point in the illustrated discussion, brought out by Mr. Horton, was the progress and advantages made possible through welded structures.

OKLAHOMA CITY

The 1940–41 Season of the Oklahoma City Section was opened with a meeting on September 12th.

The program committee has been active during the summer months and in conjunction with committees from the Kansas City, Wichita and Tulsa Sections, has arranged for a full list of speakers for the year's meetings.

Mr. K. B. Banks, chairman of the Section, has appointed a committee under the direction of O. T. Barnett to administer the proposed award of a year's membership in the Welding Society to the outstanding engineering graduate of Oklahoma A. & M. and Oklahoma University.

PHILADELPHIA

The regular monthly meeting of the Philadelphia Section was held on September 16th. Mr. J. H. Deppeler of Metal and Thermit Corporation, presented an address on "Design and Manufacture of Welding Electrodes."

The following is the schedule of meetings for the 1940–41 season.

October 14, 1940—"Oxyacetylene Flame Cutting Developments and Applications," by representative of Air Reduction Sales Company.

November 18, 1940—"Welding of Low Alloy Steels," J. E. Waugh, General Electric Company.

January 20, 1941—"Arc Welding in Small Ship Construction," J. Murray Watts, Consulting Engineer & Naval Architect.

February 17, 1941—"The Unionmelt Welding Process and Its Industrial Application," F. G. Outcalt, The Linde Air Products Company.

March 17, 1941—"Building Construction by Welding"—Section Round Table Discussion—H. W. Lawson, Bethlehem Steel Co.

April 21, 1941—"Railroad Application of Arc Welding"—tentative.

May 1941—Section Inspection Trip.

PUGET SOUND

Tentative meeting dates set by the Puget Sound Section for the next few months are: October 21st, November 18th and December 16th.

At the first monthly meeting of the 1940–41 season held on September 23rd, Mr. Frank Conrad, chairman of the Building Code Committee, gave a résumé of the high points of the tentative Welding Code for the City of Seattle.

SAN FRANCISCO

The first meeting of the season of the San Francisco Section was held on September 20th at the Athens Athletic Club, Oakland. Mr. Hugh Brown of The Brown Bros. Welding Co., San Francisco, talked on the construction of the 263-mile Boco Concession Pipe Line through the jungles of Columbia, South America. Mr. Brown's talk was illustrated with moving pictures.

TULSA

Mr. E. C. Chapman, of the Combustion Engineering Co., spoke at the first meeting of the new season, held on September 13th at the Mayo Hotel. Mr. Chapman, one of the best qualified men in the profession to talk on the subject, spoke on "Trends in Welding Development," with projected slides for illustration.

WESTERN NEW YORK

The Western New York Section of the AMERICAN WELDING SOCIETY will begin the coming season with a dinner meeting to be held at the Hotel Buffalo, Friday evening, October 18, 1940. Dinner at 6:30 P.M. after which Mr. A. E. Gibson, past-president of the Society and president of the Wellman Engineering Company of Cleveland will address the meeting on "The Welding of Low-Alloy Steels." Mr. Gibson's address will deal with the application of low-alloy steels to structural and mechanical equipment.

Those members and friends who will be unable to be present for the dinner are urgently requested to attend the business meeting, as the subject of the evening will be unusually interesting.

Inasmuch as a large attendance is expected, dinner reservations should be made at an early date. This can be done by contacting the Officers or Members of the Entertainment Committee.

Under the able direction of Chairman George M. Trefts, 3rd, assisted by officers and members, a drive to increase the section membership is under way.

Already several new memberships have been obtained and an effort is being made to have all industrial plants in the Niagara Frontier and Western New York represented.

YORK-CENTRAL PENNSYLVANIA

Mr. Edward J. Brady, Vice-President and General Manager of Alloy Rods Corp., York, Pa., was the speaker at the September 23rd meeting. His subject was on "Arc Welding the Stainless Steels." Mr. Brady's talk covered the entire range of stainless analysis from the 4–6% chromium steels to the high-alloy nickel chromium steels and placed special emphasis on the metallurgy of the stainless steels in relation to the welding procedure.

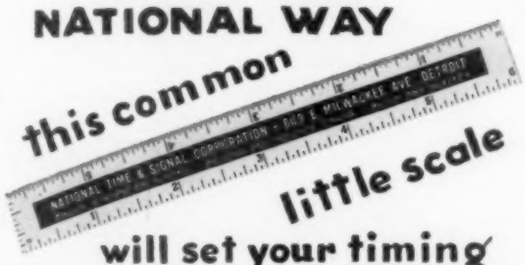
MAKE YOUR RESERVATIONS NOW!

We have been advised by the Cleveland Hotel that the rooms assigned to the AMERICAN WELDING SOCIETY are filled to capacity. Any member who has received a declination to his reservation is urged to promptly get in touch with the Hotel Hollander. The Society has made arrangements with this hotel to take care of extra reservations. However, these are going fast. First come—first served. Act now.

WHY NOT *See* WHAT'S GOING ON INSTEAD OF IMAGINING IT?

THAT'S THE NATIONAL WAY

this common

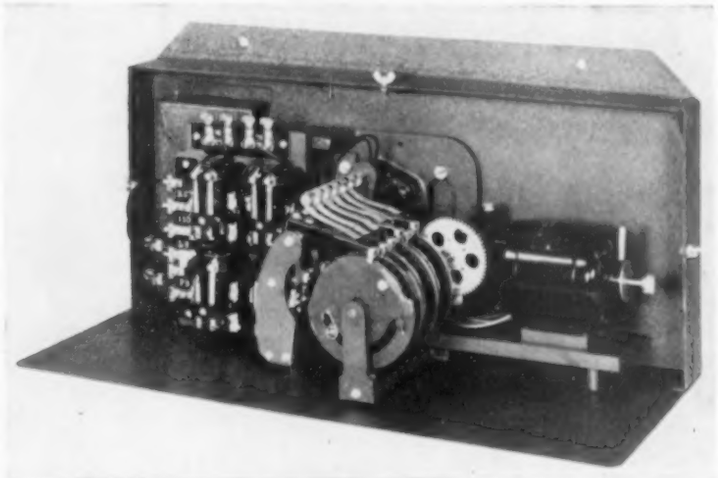


little scale

will set your timing accurately & without guesswork

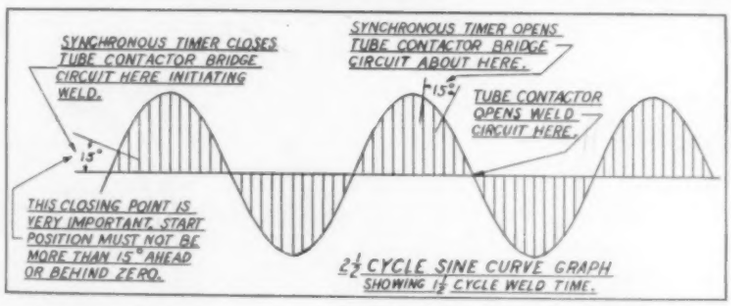
National Timers

For



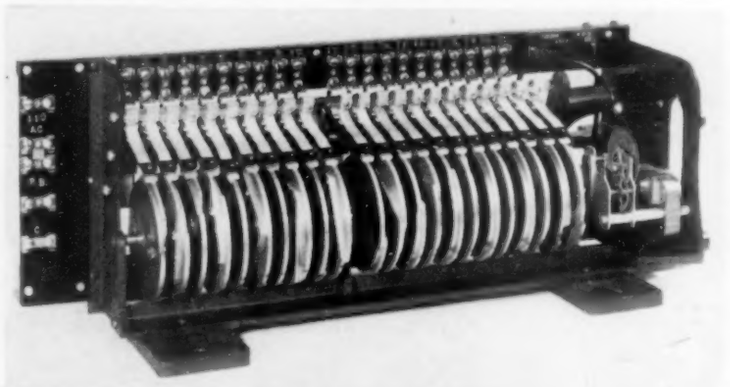
Stainless Steel or Aluminum Spot Welding—

are SYNCHRONIZED to the Welding Current Frequency.


SYNCHRONOUS TIMER CLOSES TUBE CONTACTOR BRIDGE CIRCUIT HERE INITIATING WELD.
SYNCHRONOUS TIMER OPENS TUBE CONTACTOR BRIDGE CIRCUIT ABOUT HERE.
15°
TUBE CONTACTOR OPENS WELD CIRCUIT HERE.
15°
THIS CLOSING POINT IS VERY IMPORTANT. START POSITION MUST NOT BE MORE THAN 15° AHEAD OR BEHIND ZERO.
2½ CYCLE SINE CURVE GRAPH SHOWING 1½ CYCLE WELD TIME.

In Welding certain Alloy Steels, and Non-Ferrous Metals, it is of utmost Importance, that the Initiating Point, of each Weld, start at, or close to, the alternating current ZERO Line.

To Select these Zero Points when using a 60 cycle power supply, the "Make" point must be Accurate to 1/1500th part of a second, and Constant.



Another National Timer—No. 1704-22 Sequence Type

Industrial Processing, in these days, demands accurate, timed intervals between sequence of operations. Here is a variable speed, 21 circuit timer, each circuit positionable, and with adjustable "on" time. Made in all sizes, 2 to 48 Circuits.

The National Type 1800P-75 Synchronized Timer, illustrated above, not only provides this Close Timing, but also takes care of the magnetic pressure-to-electrode air valves in timed Sequence. Weld time (from 1/2 to 10 Cycles) is obtained by rotating the "off" weld cam to position desired. The critical "on" weld cam, after being positioned, to correspond to any power factor condition of its welding transformer, remains fixed.

Welding speeds may be varied from 30 to 240 maximum welds per minute, by a simple change-gear combination.

National Synchronized Timers, similar to the Standard Type, are available for numerous welding functions, including the following, most popular:-

Momentary Push—Non-Repeat—Single Spot—Type 1800P

Non-Beat—Repeat—Generally used with Guns—Type 1840P

Combination Repeat—Non-Repeat—Switch controlled—Type 1860P

Momentary Push—Pressure Switch to Initiate Weld—Non-Repeat Type 1880P.

Indicate Speed desired by adding numerical suffix.

NATIONAL TIME & SIGNAL CORPORATION

600 E. MILWAUKEE AVENUE DETROIT, MICHIGAN

FIFTEEN YEARS PROGRESS BY RESISTANCE WELDING

SPOT WELDING ✓

BUTT WELDING ✓

SEAM WELDING ✓

PROJECTION WELDING ✓

ALL FOUR ARE RESISTANCE WELDING

Investigate them at the Metal Show

● Drop in at the Association Booth—No. B-32—where any of these processes may be discussed with welding engineers without obligation. Numerous accomplishments of resistance welding and new developments in the industry will be explained. You are cordially invited to visit with us.

IF you are unable to attend the Metal Show and the meetings of the American Welding Society at Cleveland, feel free to write any of the member companies here listed for information on any phase of resistance welding.

RESISTANCE WELDER

MANUFACTURER'S ASSOCIATION

505 Arch Street Philadelphia, Pa.

RESISTANCE WELDER MANUFACTURERS ASSOCIATION • RWMA

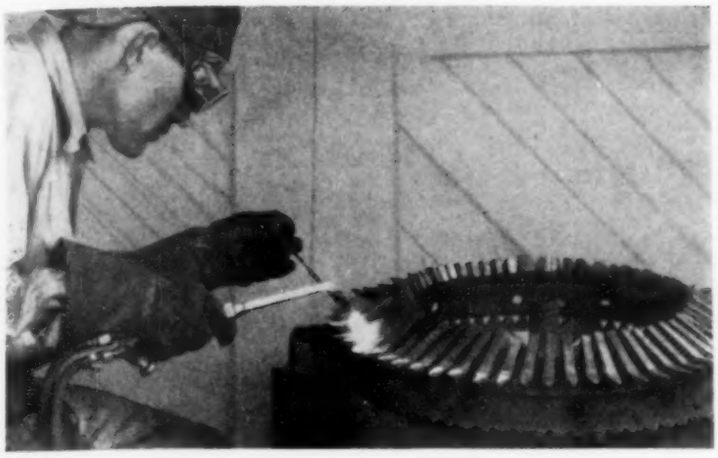
MEMBER COMPANIES

Expert Welding Machine Co., Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Co., Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Cal.
American Electric Fusion Corporation, Chicago, Ill.
Eisler Engineering Company, Newark, N. J.

ASSOCIATE MEMBER COMPANIES

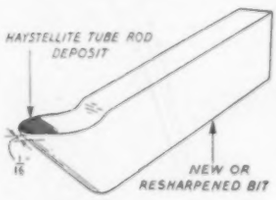
Welding Sales and Engineering Co., Detroit, Mich.
P. R. Mallory and Co., Indianapolis, Ind.
S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York City

HAYNES STELLITE COMPANY has a Hard-Facing Rod for every kind of Wearing Part . . .



Jig Speeds Application of HAYSTELLITE TUBE ROD to Coal Bits

• The rotating jig shown here increases production in hard-facing coal undercutter bits because it spaces the bits so that while hard-facing one bit, the welding flame preheats the next bit. It also permits the operator to remain in one position and supports the bits so that the surfaces to be hard-faced are horizontal. When coal bits are hard-faced with Haystellite tube rod they stay sharp many times longer, reducing power consumption and down time for bit changes.



Haystellite tube rod is used for this job because the conditions of service require maximum resistance to abrasion without particular regard for impact resistance, corrosion resistance, or surface polish.

Haynes Stellite engineers and service operators of The Linde Air Products Company can show you many other ways to obtain greater savings from hard-facing. Call on them, without obligation.

Headquarters for Hard-Facing Materials

HAYNES STELLITE COMPANY

Unit of Union Carbide and Carbon Corporation

New York, N. Y. UCC Kokomo, Indiana

Chicago–Cleveland–Detroit–Houston–Los Angeles–San Francisco–Tulsa

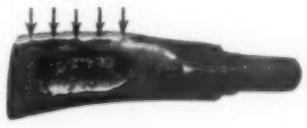
and *experienced sales engineers to help you select and use them effectively—*

Hard-Facing Hints

HASCROME rod was used for hard-facing these shovel teeth because they were for use in rocky formations where high impact-resistance and work-hardening properties are required. If the shovel were

used to handle silt, clay, sandstone, or other loose, homogeneous materials, Haynes Stellite or Haystellite alloys would give longer service.

HAYNES STELLITE No. 1 hard-facing rod was used on this thresher tooth as indicated by the arrows, because of the abrasive nature of the work and the need for a smoothly finished surface.



Notice that after use on 3,200 acres, the hard-facing material is merely polished, although teeth not hard-faced are dull after only 1,200 acres.

Hard-facing applications in many industries are described and illustrated in the book, "Hard-Facing with Haynes Stellite Products." A copy will be sent on request.

"Haynes Stellite," "Haystellite," and "Hascrome" are registered trade-marks of Haynes Stellite Company

Attend American Welding Society's annual meeting . . . . and National Metal Exposition . . . . at Cleveland during October 21 to 25. . . . Hear authorities discuss latest developments in hard-facing materials and methods. . . . Exchange ideas with other experts. . . . Write now for program.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-96. Wanted Welding Engineer. Will be responsible for welding procedures, welding technique and qualification of welders. Must have experience as a metallurgist. Headquarters will be in shop, controlling welding operations. Man should have full knowledge of welding stainless steel alloys, carbon steel, Everdur, Monel metal, nickel. Should be familiar with code requirements, Navy specifications, X-ray and Magnaflux.

V-97. Welding Engineer, graduate metallurgist with experience in welding practice.

SERVICES AVAILABLE

A-376. Welding Engineer desires position. 35 years of age. 14 years of welding experience as welder, supervisor, inspector and instructor. Familiar with layout work.

A-377. Welding Superintendent desires position with going concern. Experienced on code welding, marine construction, aircraft welding, general maintenance welding. Can meet the public, get along with men. Sales experience. Free to travel. Will take foreign work, speak fair Spanish. Best references.

A-378. Electric Welder. Six years' experience in shipyards.

A-379. Test Welder, college graduate, also metallurgy student. Has been with prominent electrode manufacturer for over two years, testing and demonstrating all types of welding electrodes in all applications. Has also had structural welding experience. Desires position as welding inspector or welding supervisor.

A-380. Electric Welder desires position. Twenty-one years' experience. Worked for Staten Island Shipyard, Federal Shipyard, American Locomotive Co., Babcock-Wilcox, and Halifax Shipyard. American born. Would like work in shipyard or manufacturing plant.

A-381. Welder, Electric Arc and Gas Cutting. Completed course with actual practice. Also Diesel training. Go anywhere. Can produce references.

A-382. Welding Engineer, nationally acquainted, desires position with metal or welding equipment manufacturer as sales and service engineer. Experienced on all metals and alloys and all welding processes, both manual and automatic. Have attended ten Metal Expositions.

CIVIL SERVICE EXAMINATIONS FOR ENGINEER POSITIONS

In connection with the National Defense Program, the United States Civil Service Commission has announced an open competitive examination to secure junior engineers for Government service. The examinations cover all branches of engineering except aeronautical, naval architecture and marine engineering. The salary of $2000 a year is subject to a retirement deduction of $3^1/_2$ per cent.

Applications must be in the Commission's Washington office not later than October 24th if received from States east of Colorado, and October 28, 1940 if received from Colorado and States westward.

Applicants must have completed a 4-year engineering course at a recognized college. They will be rated on a written examination consisting of general and professional questions. The maximum age limit is thirty-five years, unless applicants are granted veteran preference.

Full information as to the requirements for the examination, and application forms, may be obtained from the Secretary of the Board of U. S. Civil Service Examiners or at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D. C.

AIRCRAFT PROCUREMENT INSPECTORS URGENTLY NEEDED

An examination has been announced, and is now open until further notice, for procurement inspectors in the Matériel Division, Air Corps, War Department, at Wright Field, Dayton, Ohio. The Civil Service Commission states that there is an urgent need to fill these positions. Qualified persons are urged to apply at once.

There are three grades of positions as follows: The full grade, paying $2300 a year; senior grade, $2600 a year; and and assistant grade, $2000 a year. The examination includes six branches of inspection work—aircraft, engines, instruments, parachutes, aircraft propellers, and tools and gages.

Applicants will not be given a written test. They will be rated upon their education and experience as shown in their applications, subject to verification by the Commission. Senior inspector applicants must have had at least seven years, inspectors at least six years, and assistants at least four years, of (*a*) mechanical experience (which may include apprenticeship) in one of the major skilled trades in the optional branch chosen, with an aircraft manufacturing plant; or (*b*) in aircraft procurement inspection; or any time-equivalent combination of the two. Applicants may substitute college courses in engineering for the experience.

Persons experienced and interested in this type of work should apply for details and the proper application forms to the Secretary, Board of U. S. Civil Service Examiners, Wright Field—Fairfield Air Depot, Wright Field, Dayton, Ohio; to the Secretary, Board of United States Civil Service Examiners at any first- or second-class post office; to the United States Civil Service Commission, Washington, D. C., or to any of the Commission's district offices.

RAILWAY BRIDGE HAS ALL-WELDED DECK

A lot of weld went into the new Pere Marquette Railway Bridge over Highway 10 at Grand Blanc, Michigan—2400 feet, to be exact. The bridge was built by L. A. Davidson, a prominent Michigan contractor, and is 300 feet long and 30 feet wide.

Photo courtesy Harnischfeger Corp., Milwaukee
Recently Completed Pere Marquette Bridge at Grand Blanc, Michigan

The deck of the Pere Marquette bridge was made of wrought iron plates welded together with $^1/_2$-inch welds. The photograph shows the bridge deck.

HIGH TENSILE STEEL PLUS ARC WELDING GIVES BIGGER "PAY LOAD"

To increase efficiency of gasoline distribution, the Gulf Oil Corporation, Pittsburgh, Pa., has had a fleet of 19 new, 3000-gallon truck tanks built of arc-welded high-tensile steel. The total reduction of unladen weight obtained by the combination of arc welding and the use of high-strength steel permits about 15 per cent more gasoline to be hauled each trip without increasing the gross weight of the load.

Fig. 1—Showing Arc-Welded, High-Tensile Steel Gasoline Truck Tanks Under Construction at the Standard Steel Works, North Kansas City, Mo.

Photos courtesy General Electric Co.
Fig 2—One of the Completed, Streamlined Gasoline Tank Trucks

Fabrication of these modern streamlined, five-compartment tanks was carried out by the Standard Steel Works of North Kansas City, Mo. An interesting phase of the work is that mild steel, shielded-arc electrode, was used for welding the high-tensile steel. Since this steel is relatively thin, sufficient influx of base metal into the joint was obtained to develop full high-tensile properties and at the same time gain the speed, ductility, and economy of this mild-steel electrode.